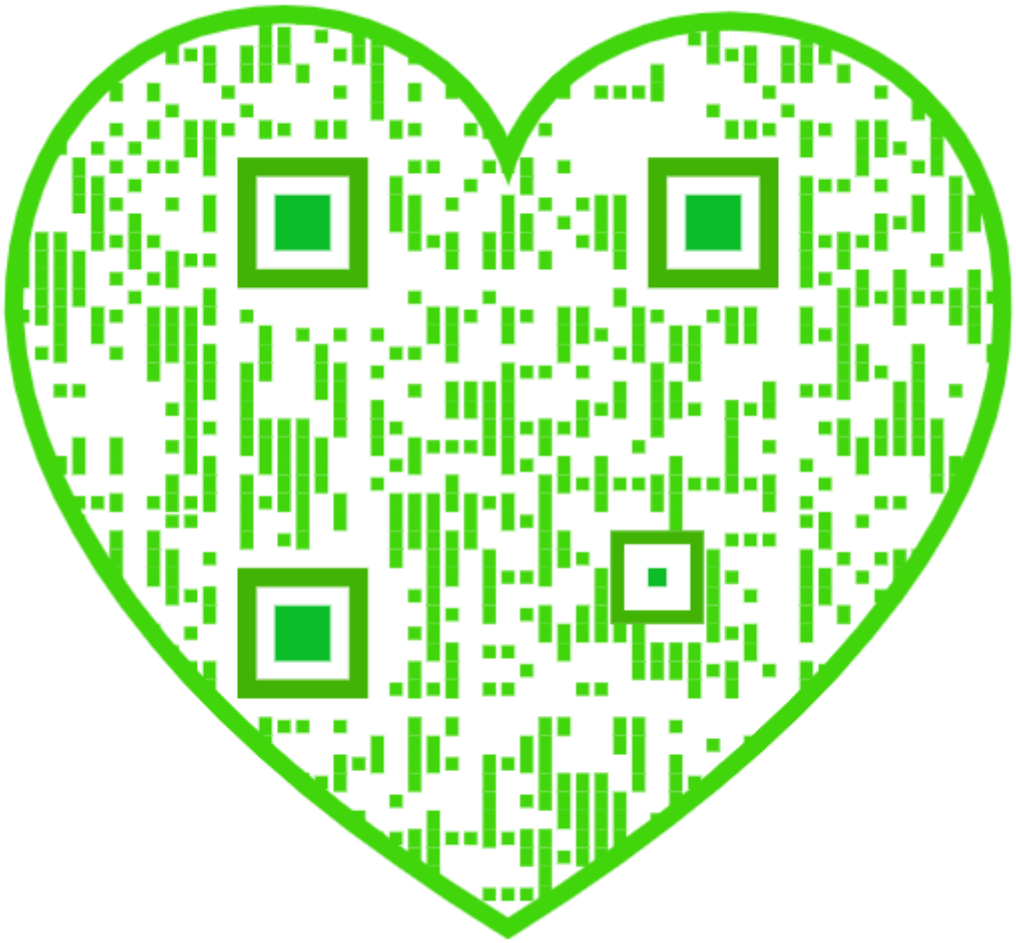

ELEMENTS

OF

MINERALOGY, CRYSTALLOGRAPHY

AND

BLOWPIPE ANALYSIS

FROM A PRACTICAL STANDPOINT

INCLUDING

A DESCRIPTION OF ALL COMMON OR USEFUL MINERALS, THE TESTS NECESSARY FOR THEIR IDENTIFICATION, THE RECOGNITION AND MEASUREMENT OF THEIR CRYSTALS, AND A CONCISE STATEMENT OF THEIR USES IN THE ARTS

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NEW ENLARGED EDITION

PARTS I AND IV REWRITTEN. PARTS II AND III EXTENSIVELY REVISED

WITH 664 FIGURES AND 413 PAGES OF TEXT

NEW YORK

D. VAN NOSTRAND COMPANY

1909

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PREFACE.

In this edition of our text-book we have adhered to the design of the edition of 1895, to present the facts leading to a useful knowledge of mineralogy in such a manner that the student in the technical school and the professional man in the field may readily learn to recognize or, when necessary, to determine all important minerals.

We have made a number of changes and additions which experience has shown to be desirable. Some of these are:

Part I., Crystallography, has been entirely rewritten to conform to the now accepted classification, and under each class there have been assembled combinations found in definite species. Over one hundred figures have been added.

Part II., Blowpipe Analysis, has been carefully revised, new figures drawn and discussions of the use of the spectroscope, and of metallic sodium added.

Part III., Descriptive Mineralogy, now includes about forty pages designed as an introduction to the later study of minerals in thin sections under the microscope. The cuts throughout the descriptive portion are new and the faces of crystal figures are lettered to facilitate the recording of angles. All crystallographic descriptions and economic discussions have been rewritten.

Part IV., Determinative Mineralogy, has been entirely rewritten and greatly simplified.

Many suggestions have been made to us by instructors using the book. In so far as possible we have acted upon these suggestions and we sincerely hope that the new edition may receive approval.

TABLE OF CONTENTS.

PART I.—CRYSTALLOGRAPHY. CHAPTERS I. TO X., PAGES 1 TO 81.

Chapter	I.	Introductory,	1–11
Chapter	II.	The Isometric System,	12–22
Chapter	III.	The Tetragonal System,	23–32
Chapter	IV.	The Hexagonal System,	33–47
Chapter	V.	The Orthorhombic System,	48–54
Chapter	VI.	The Monoclinic System,	55–60
Chapter	VII.	The Triclinic System,	61–64
Chapter	VIII.	Twinned Crystals,	65–71
Chapter	IX.	Measurement of Crystal Angles,	72–75
Chapter	X.	Crystal Projection or Drawing,	76–81

PART II.—BLOWPIPE ANALYSIS. CHAPTERS XI. TO XIV., PAGES 83 TO 135.

Chapter	XI.	Apparatus Blast, Flame, etc.,	83–89
Chapter	XII.	Operations of Blowpipe Analysis,	90–109
Chapter	XIII.	Summary of Useful Tests with the Blowpipe,	110–124
Chapter	XIV.	Schemes for Qualitative Blowpipe Analysis,	125–135

PART III.—DESCRIPTIVE MINERALOGY. CHAPTERS XV. TO XXXV., PAGES 137 TO 395.

Chapter	XV.	Characters of Minerals,	137–153
Chapter	XVI.	Optical Characters,	154–163
Chapter	XVII.	Optical Characteristics of the Different Crystal Systems	164–179
Chapter	XVIII.	The Thermal, Magnetic and Electrical Characters,	180–186
Chapter	XIX.	Chemical Composition and Reactions,	187–193
Chapter	XX.	The Iron Minerals,	194–213

PART III.—DESCRIPTIVE MINERALOGY—*Continued.*

Chapter XXI. The Manganese Minerals,..... 214–218
Chapter XXII. Nickel and Cobalt Minerals,..... 219–226
The Cobalt Minerals, ... 219
The Nickel Minerals,..... 222
Chapter XXIII. Zinc and Cadmium Minerals, ... 227–233
The Zinc Minerals,..... 227
The Cadmium Minerals,.... 233
Chapter XXIV. Tin, Titanium and Thorium Minerals, 234–240
The Tin Minerals,..... 234
The Titanium Minerals,..... 236
The Thorium Minerals,..... 239
Chapter XXV. Lead and Bismuth Minerals, ... 241–254
The Lead Minerals,..... 241
The Bismuth Minerals, ... 251
Chapter XXVI. Arsenic, Antimony, Uranium and Molybdenum Minerals, ... 255–262
The Arsenic Minerals, ... 255
The Antimony Minerals, ... 257
The Uranium Minerals, ... 260
The Molybdenum Minerals, 261
Chapter XXVII. The Copper Minerals, ... 262–275
Chapter XXVIII. Mercury and Silver Minerals,..... 276–285
The Mercury Minerals,..... 276
The Silver Minerals,..... 278
Chapter XXIX. Gold, Platinum and Iridium Minerals, ... 286–290
The Gold Minerals, ... 286
The Platinum and Iridium Minerals, ... 289
Chapter XXX. Potassium, Sodium and Ammonium Minerals,..... 291–297
The Potassium Minerals,..... 291
The Sodium Minerals,..... 293
The Ammonium Minerals, . 297
Chapter XXXI. Barium and Strontium Minerals,..... 298–302
The Barium Minerals,..... 298
The Strontium Minerals,..... 300
Chapter XXXII. Calcium and Magnesium Minerals,.... 303–320
The Calcium Minerals, ... 303
The Magnesium Minerals, .. 317

PART III.—DESCRIPTIVE MINERALOGY—*Continued.*

Chapter XXXIII. The Aluminum Minerals,..... 318–330

Chapter XXXIV. Boron, Sulphur, Tellurium, Hydrogen and Carbon Minerals,.... 331–342
The Boron Minerals,..... 331
The Sulphur and Tellurium Minerals..... 335
The Hydrogen Minerals,.....337
The Carbon Minerals,.....338

Chapter XXXV. Silica and the Silicates,..... 343–395
Silica, ...346
Polysilicates,.....351
Metasilicates,.....357
Orthosilicates, ...367
Basic- or Subsilicates, ...381
Hydrous Silicates,.....383
Titano-Silicates, ...395

PART IV.—DETERMINATIVE MINERALOGY. PAGES 397 TO 399 AND INSETS.

Chapter XXXVI. Tables for Rapid Determination of the Common Minerals,..... 397

I. Minerals of Metallic or Submetallic Lustre.

II. Minerals of Non Metallic Lustre,

A. With Decided Tastes, that is. Soluble in Water.

B. Without Taste but yielding Coating or Magnetic Residue when Heated on Charcoal.

C. Tasteless, non Volatile and NOT made Magnetic by Heating on Charcoal.

Table of Atomic Weights,..... 399

GENERAL INDEX,..... 401–409

INDEX TO MINERALS,..... 410–413

PART I.

CRYSTALLOGRAPHY.

CHAPTER I.

INTRODUCTORY.

Crystals and Crystallization.

Crystals are formed only when a chemical element or a chemical compound solidifies. Broadly speaking every such solidification is a crystallization and must result in the formation of either:

(*a*). CRYSTALS,* that is, distinct solids bounded by plane faces at definite angles to each other, or

(*b*). Masses which are aggregations of crystals, that have been hindered in development by lack of space or time or other cause.

It is assumed that the invisible molecules of the substance during solidification are so drawn together that each becomes the center of a precisely similar group, and that along any line, and all parallel lines, the particles are equally far apart. Certainly in a solidification the first visible solid particles, are bounded by plane faces at definite angles to each other, and although at later stages of the solidification the crystals may be larger, the angles between the faces do not change.

That a regular arrangement of the particles has taken place can be shown even in the absence of distinct crystals. For instance, solid masses will often break or cleave in directions parallel to certain crystal faces yielding frequently polyhedral solids absolutely constant in angles, no matter how far the cleaving is continued or how small the resulting solids may be. It is also thoroughly

* By the term "crystal" was originally meant the colorless quartz still called rock crystal, which was found in geometric solids in many localities and supposed to be water frozen at an extremely low temperature.

proved that in definite chemical solids the velocity of transmission of light, is exactly the same in all *parallel* directions, but is not necessarily or even generally the same in directions not parallel; whereas in glass or other homogeneous solids which are not definite chemical compounds the velocity of transmission is, generally speaking, the same in *all* directions and portions, or if unlike it is without any regularity of difference.

The same constancy for parallel directions and variation for directions not parallel is shown for other physical characters such as expansion from heat, conductivity of heat or electricity, and even color and lustre, proving beyond reasonable doubt the regular constant arrangement of the particles in straight lines and planes.

LAWS OF CRYSTALS.

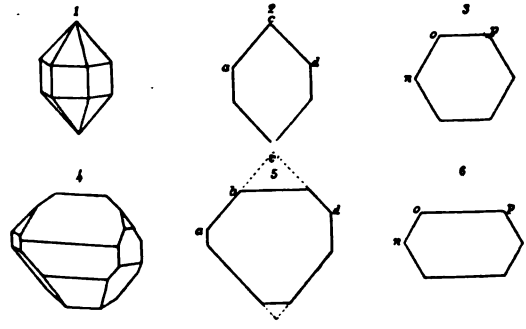
The polyedral solids or CRYSTALS which so frequently result from a solidification are infinite in variety. Each substance may occur in a large number of different shapes, no two exactly alike, yet extended observation has shown that they follow certain laws with absolute fidelity.

The three *great* laws of crystals are:

1°. THE LAW OF CONSTANCY OF INTERFACIAL ANGLES.
2°. THE LAW OF SYMMETRY.
3°. THE LAW OF SIMPLE MATHEMATICAL RATIO.

Law of Constancy of Interfacial Angles.

FIGS. 1–6.



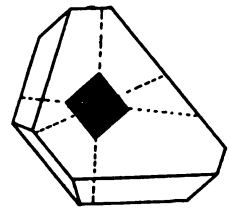
The variations between crystals of any one substance are limited by the following law:

*In all crystals of the same substance the angles between corresponding faces are constant.**

Figures 1 and 4 represent actual crystals of quartz. Figures 2 and 5 are sections of these in the direction of the plane of the paper which show that the angles between corresponding edges are equal. The same is shown by the horizontal sections, Figs. 3 and 6.

Similarly in Fig. 7 the faces of the magnetite crystal are exactly parallel to those of the ideal octahedron represented within it, that is, such crystals of magnetite are bounded by faces which may or may not be equal in size but in which the angle between adjacent faces must be 109° 28′ 16″.

FIG. 7.



Law of Symmetry.

In any crystal, faces and angles of the same kind are repeated with some degree of regularity.

This regularity is called the symmetry of the crystal, and its law may be stated as follows :

All crystals of any one substance are of the same grade of symmetry.

To understand this law certain definitions and explanations are essential.

A crystal is *symmetrical to the center* when every straight line through the center encounters at equal distances on each side of the center two corresponding† points of the crystal.

A crystal is *symmetrical to an axis* when if revolved about this axis the crystal reoccupies the same position in space, two, three, four, or six times during one complete revolution. That is, corresponding groups of planes exchange positions after revolutions of 180°, 120°, 90° or 60°.

The crystal of gypsum, Fig. 8, is symmetrical to the axis *BB ;* for, as shown in Fig. 9 both when the point *a* has moved to *b* or again to *a* the crystal occupies the original position in space. Moreover for any intermediate position of *a* such as *c* the space oc-

* Steno in 1669 announced that in rock crystal there was no variation of angle in spite of the variation in relative size of the faces.

Romé Delisle in 1783 measured and described over four hundred crystal forms and announced that in each species "the respective inclination of the faces to each other never varies."

† For instance, the centers of similar edges or the intersections of similar lines, or the centres of similar faces or vertices of similar polyhedral angles.

cupied is distinctly not the same. That is, *BB* is an axis of *two-fold or binary* symmetry.

FIG. 8.

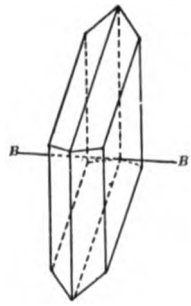
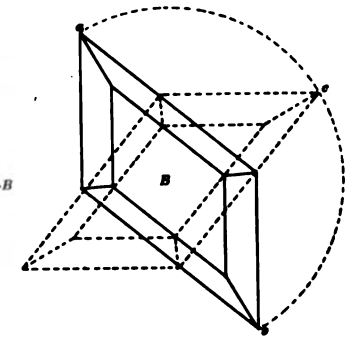


FIG. 9.



The crystal of calcite, Fig. 10, has several axes of symmetry. Of these the vertical axis *c* is an axis of *threefold or trigonal* symmetry for, as seen in horizontal projection,

FIG. 10.

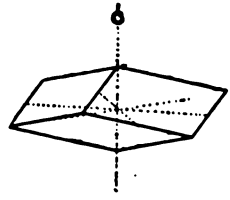


FIG. 11.

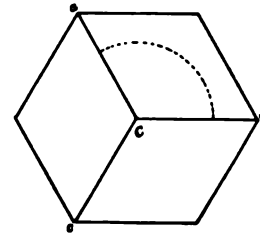


Fig. 11, when *a* has moved to *b* or to *c* or again to *a*, the crystal occupies the same position in space.

FIG. 12.

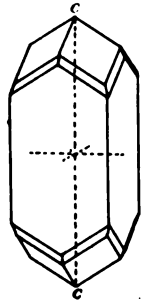


FIG. 13.

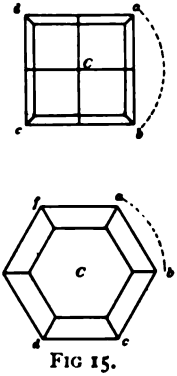


FIG. 14.

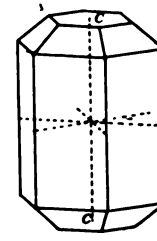


FIG 15.

The line *CC* in the zircon crystal, Fig. 12, is an axis of *fourfold* or *tetragonal* symmetry, for, as shown in the horizontal projection, Fig. 13, the crystal occupies the same

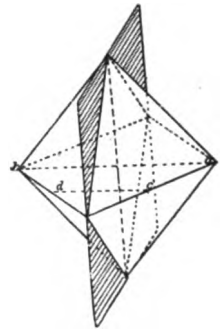
position in space when any point *a* has moved to *b*, *c*, *d* or again to *a*, and does not for any other position.

Finally the line *CC* in the apatite crystal, Fig. 14, is an axis of *sixfold or hexagonal* symmetry, because, as shown in horizontal projection, Fig. 15, the crystal occupies the same position in space when any point *a* has moved to *b*, *c*, *d*, *e*, *f* or again to *a*.

A crystal is *symmetrical to a plane* when the plane so divides the crystal that either half is the mirrored reflection of the other, and every line perpendicular to the plane connects corresponding parts of the crystal and is bisected by the plane of symmetry.

Thus in Fig. 16 the shaded plane so divides the crystal that a line from an angle *b* perpendicular to the plane passes through a corresponding angle *a*, or a perpendicular from *c*, the center of an edge, passes through *d*, the center of a similar edge.

FIG. 16.



True Structural Symmetry.

The true structural symmetry of a crystal is known only when all the characters have been considered. Structurally equivalent directions not only imply similar groupings of bounding faces but physical identity in all respects and two directions are not structurally equivalent if in these directions there is revealed any essential difference in behavior with polarized light or etching or pyro-electricity or with any other test, the results of which depend upon the manner the crystal molecules are built together.

Classes of Symmetry.

Theoretically there have been distinguished thirty-two classes of symmetry, that is, thirty-two varieties of regular molecular arrangement. The crystals corresponding to these classes differ in the number and relative position of their axes and planes of symmetry, but all crystals of the same substance necessarily belong to the same class.

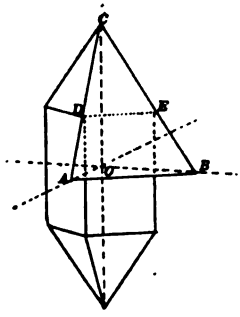
By far the greater number of crystals of minerals belong to seven of the classes.

Crystallographic Axes.

The faces, or bounding planes, of crystals are most conveniently defined in position by the methods of Analytical Geometry. Three (in one system four) straight lines passing through the center of the crystal are chosen as crystallographic axes and any face *CDE*,

Fig. 17, is defined in position by its axial intercepts, that is by the distances *OA*, *OB* and *OC* along each axis from the center to the intersection with the plane *ABC* of which the face *CDE* is a part. The crystallographic axes are chosen to yield the simplest relations, and are therefore always lines closely related to the symmetry, that is: axes of symmetry, lines normal to planes of symmetry, or where these are not to be had, lines parallel to at least two faces of the crystal.

FIG. 17.



Interchangeable Axes.

If the grouping of the faces about one axis is just the same as the grouping of the faces about another axis so that when the axes exchange positions the appearance of the crystal is not altered, the axes are said to be "interchangeable."

It may be noted that if one crystallographic axis is also an axis of trigonal, tetragonal or hexagonal symmetry, the other crystallographic axes will be at right angles to it *and interchangeable.*

The Six Systems of Crystallization.

The thirty-two classes of symmetry may be united in the following six systems by grouping together classes in which the crystallographic axes are similarly related:

THE ISOMETRIC SYSTEM.—Three interchangeable axes at right angles to each other.

THE TETRAGONAL SYSTEM.—Three axes at right angles, of which two are interchangeable.

THE HEXAGONAL SYSTEM.—Four axes, three of which lie in one plane at sixty degrees to each other and are interchangeable, the fourth is at right angles to the other three.

THE ORTHORHOMBIC SYSTEM.—Three axes at right angles but not interchangeable.

THE MONOCLINIC SYSTEM.—Three non-interchangeable axes two of which are oblique to each other, the third is at right angles to the other two.

THE TRICLINIC SYSTEM.—Three non-interchangeable axes at oblique angles to each other.

Determination of System.

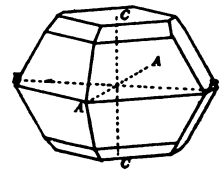
There will be exactly the same grouping of planes at the opposite "ends" of an axis and at the ends of interchangeable axes, that is these "ends" will lie in similar geometric parts.

The crystal axes, as stated, p. 6, will be preferably axes of symmetry or normals to planes of symmetry or at least parallel to two crystal faces.

By viewing the crystal in different positions and noting the shape and recurrence of similar parts, it will be seen whether the line of sight is a satisfactory direction for an axis.

With natural crystals not of ideal shape, more practice is needed to recognize similar groupings of faces. A hand goniometer is of great assistance.

FIG. 18.



For instance, the appearance of the sulphur crystal, Fig. 18, viewed in the direction *AA* is shown in Fig. 19. Evidently the line of sight (*AA*) is an axis of symmetry for Fig. 19 revolved 180° about *A* is unchanged in appearance. Moreover, the two lines through *A*, Fig. 19, are lines of symmetry, corresponding to planes of symmetry in Fig. 18, and suggest two other crystal axes normal to these planes.

FIG. 19.

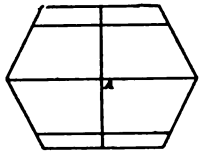


FIG. 20.

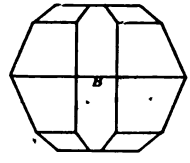
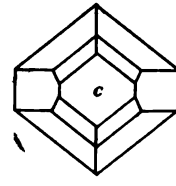


FIG. 21.



When the crystal, Fig. 18, is viewed in the direction *BB*, Fig. 20, or of *CC*, Fig. 21, the axes suggested by Fig. 19 are confirmed. No other directions yield lines of symmetry hence the crystal axes are *AA*, *BB* and *CC*, Fig. 18, which are not interchangeable and the system is orthorhombic.

In crystals of the higher grades of symmetry inspection may show more possible crystal axes than are needed. Preference must then be given :

(*a*) To directions at right angles to each other.

(*b*) To interchangeable directions.

If only one direction is found normal to a plane of symmetry or itself an axis of symmetry this direction must be taken as one of the axes and the other two must be chosen each normal to the first and parallel to at least two faces.

If no lines of symmetry are found the axes chosen should each be parallel to at least two faces.

Crystal Forms.

A crystal may be one crystal form or a combination of two or more forms. All faces of a crystal form must cut the crystal axes at the same relative distances from the center and there must be just enough faces to satisfy the symmetry of the crystal. If only two faces are required then these two constitute a "form."

Ideal Crystal Forms in Drawings and Models.

It is convenient, in elementary work, to make use of models and drawings of crystal forms in which all corresponding faces are equal in size and at equal distances from the center. Such a form may be said to be derived from the form in which a natural crystal occurs by moving each face parallel to itself until all corresponding faces are at an equal distance from the center. Thus in Fig. 7 the little inner octahedron is the ideal form of the outer actual form, and Fig. 1 is the ideal form of Fig. 4.

Law of Simple Mathematical Ratio.

Experience proves that a very exact law limits the number of different crystal forms which ever occur upon crystals of the same substance. This relation, which is variously known as: "The Fundamental Law of Crystallography," "The Law of Simple Mathematical Ratio" and "The Law of Rational Indices," may be expressed as follows:

In all crystals of the same chemical substance, if the intercepts of ANY *face upon the crystallographic axes are divided,* term by term, by the corresponding intercepts of* ANY OTHER *face, the quotients will always be simple rational numbers or infinity or zero.*

For example, if in a crystal of a given substance the axial intercepts are determined for one face to be relatively 0.813 : 1 : 1.903 then another face could occur in such a position that its intercepts in the same order would be relatively 1.626 : 1 : 5.709 because $\frac{1.626}{0.813} = 2$ and $\frac{5.709}{1.903} = 3$, but a plane with intercepts relatively 1.734 : 1 : 6.275 *could not occur upon this crystal or upon any other crystal of this substance* because $\frac{1.734}{0.813} = 2.1328 +$ and

* The intercepts are always reduced so that the corresponding term in each is unity.

$\frac{6.275}{1.903} = 3.2973 +$ that is, the quotients obtained by dividing corresponding terms are not simple numbers or infinity.

Crystal Habit.

All crystals of the same substance must be bounded by faces belonging to one series of crystal forms connected by the fundamental law. In theory any one form or all may occur bounding the same crystal; or each crystal may show a different combination.

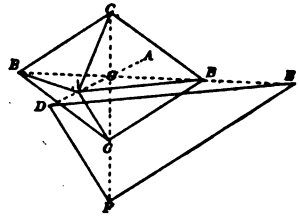
In actual experience, however, the crystals of a substance if found at the same locality or formed in the same experiments show a well defined "HABIT," that is the same forms occur on all or nearly all of the crystals, and usually the same one or two forms so predominate as to constitute the greater portion of each crystal and the other occurring forms are present as relatively inconspicuous faces or sometimes entirely absent.

At another locality or from a change in laboratory conditions the crystals of this substance may show very different predominating faces though *necessarily faces of the same series.*

The Weiss Symbols and Parameters.

To represent a crystal form a symbol must be equally satisfactory for all faces of the form, and be quite independent of the absolute position of these faces so that it may be applicable to crystals of all sizes and to the most unequally developed forms.

FIG. 22.



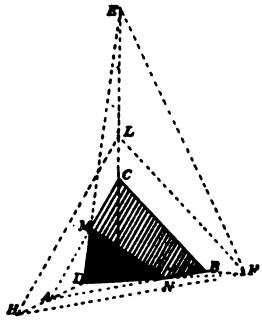
If the intercepts are stated as a ratio then evidently these conditions are fulfilled. For the ratio $OA : OB : OC$, Fig. 22, not only represents the face ABC and (disregarding *direction* of intercepts) the other faces $A'B'C'$, etc., of the ideal form, but it represents equally well a parallel plane DEF in which $OD : OE : OF = OA : OB : OC$.

But a satisfactory symbol should also show the simple relation between the forms of the series. To accomplish this Professor Weiss denoted the axial intercepts of some selected and usually prominent form in each series by a, b and c corresponding respec-

tively to intercepts upon the axes AA, BB and CC of Fig. 22 and wrote as the *symbol* of this selected unit face $a:b:c$.

The symbol of any other face in the series was written *in terms of* a, b, and c and was necessarily such a symbol as $2a:b:c$; $a:3b:\frac{1}{2}c$ or $a:\infty\ b:3c$ the coefficients or *parameters* being, because of the simple mathematical ratio, always simple numbers, simple fractions, or infinity.

FIG. 23.



To illustrate: Let $BCMN$ and DMN, Fig. 23, be two faces of a crystal. Prolong $BCMN$ to the axes, then are OA, OB and OC its axial intercepts and if this plane is chosen as the unit plane then $a:b:c = OA:OB:OC$.

Prolong DMN to the axes, then are OD, OF and OE the intercepts of DMN. Through one of the points D, E or F, for instance F, construct a plane FHL parallel to the unit face, then also $OH:OF:OL = a:b:c$.

If these faces obey the fundamental law, since one intercept of DMN and FHL is the same, the quotient of the others, that is,

$$\frac{OD}{OH} \text{ and } \frac{OE}{OL}$$

will be *simple* finite numbers or infinity.

In the construction $OD = \frac{1}{3}OH$ and $OE = 2OL$, hence if the symbol of $BCNM$ is taken as $a:b:c$, that of DMN *in comparison* is $\frac{1}{3}a:b:2c$ or it could be written $a:3b:6c$ or $\frac{1}{6}a:\frac{1}{2}b:c$.

When a face is parallel to an axis it is said to intersect it at an infinite distance and the sign ∞ is used to express infinity.

The Dana Symbols consist of the vertical parameter, a dash, and the other parameter. For instance

$5\breve{a}:\bar{b}:\frac{5}{3}\dot{c}$ becomes $\frac{5}{3}-5$ $\quad a:na:ma$ becomes $m-n$.

The Miller Indices may be obtained from Weiss's parameters by first dividing each by the common multiple of their numerators and taking the reciprocal of the result. That is $5a:b:\frac{5}{3}c$ becomes $a:\frac{1}{5}b:\frac{1}{3}c$ and the Miller's symbol is 153.

When the symbol is enclosed in brackets *e. g.* {153}, it is understood to typify the form, but when in parentheses it signifies the individual face (153).

Determination of Ideal Forms or Models by Inspection.

After the axes have been chosen, as described p. 6, and placed in the conventional positions stated under each system, the determination of form and symbol may be conducted as follows:

Place a straight edge (or pencil) in contact with a face and turn the straight edge always as a line *in* the face until its relation to each axis has been noted. The absolute values of the axial intercepts (from the center of crystal to where the straight edge intersects the axes) are not needed in determining the *type* of form; all that is essential is to distinguish the greater intercept from the lesser or at most a very rough approximation to their relative lengths.

If it is not evident that all the faces of the figure hold the same relation to the axes, any supposedly different face is tried in precisely the same way with the straight edge and with respect to the *same* axes. In ideal crystals and models faces of the same form are equal in size and of the same shape.

CHAPTER II.

ISOMETRIC SYSTEM.

The Isometric* system includes all crystal forms which can be referred to three interchangeable axes at right angles to each other.

In models and drawings representing ideal forms these axes are equal in length, but in actual crystals they are merely directions about which there are equal numbers of faces grouped with corresponding faces at the same angles. The faces are not usually equal in size.

The crystal or model is turned until one axis is vertical, one extends from left to right, and one from back to front.

In stating the relative distances, from the center, at which any face cuts the three axes, the shortest distance is called *a* and the other distances, since the axes are interchangeable, are simple (or infinite) multiples of *a*.

According to the number and arrangement of the planes and axes of symmetry, isometric crystals have been divided into five classes. A given substance can only occur in forms of one class. Three of the classes include nearly all known isometric minerals.

In describing the forms of a class the most general form "the faces of which intersect the three axes at any distances permitted by the fundamental law" is first described and then the six limit forms corresponding to special positions of the faces of the general form.

HEXOCTAHEDRAL CLASS. 32.

No. 1. Holohedral, *Liebisch.* No. 1. Normal Group, *Dana.*

Symmetry of the Class.

The planes of symmetry are represented in Fig. 24 and the axes of symmetry in Fig. 25. The small black squares and triangles indicate axes of tetragonal and trigonal symmetry respectively. The tetragonal axes are chosen as the crystal axes.

* Also called Tesseral, Tessular, Regular, Cubic and Monometric.

FIG. 24.

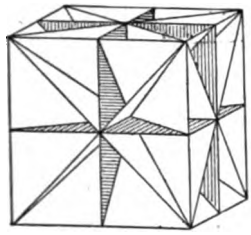
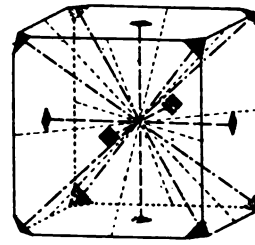


FIG. 25.



THE GENERAL FORM OR HEXOCTAHEDRON.

Weiss, $a : na : ma$; Dana, $m - n$; Miller, $\{hkl\}$.

Composed of forty-eight faces each cutting the three axes in three different, but simply proportionate distances. In the ideal forms the faces are scalene triangles.

FIG. 26.

FIG. 27.

FIG. 28.

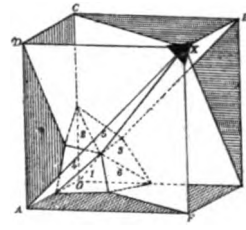


Fig. 26 shows the form $a : \frac{3}{2}a : 3a$ for which the diedral angles A, B, C, Fig. 27, are

$$A = 158° 13'; \; B = 149°, \; C = 158° 13';$$

Fig. 27 shows $a : 2a : 4a$ for which

$$A = 162° 15'; \; B = 154° 47', \; C = 144° 3'.$$

That the symmetry of the group requires forty-eight such faces to satisfy it may readily be proved by Fig. 28 which is simply an eighth (or octant) of Fig. 24 enlarged, O being the center, OA, OB and OC the crystal axes and OX an axis of trigonal symmetry. If any face 1, with intercepts on OA, OB, OC respectively, $1 : 3 : \frac{3}{2}$ occurs, it must be accompanied by faces 2 and 3 because OX is an axis of trigonal symmetry, and the three white planes of symmetry make necessary planes 4, 5 and 6. Finally the entire octant must be reflected in each of the other octants by the shaded planes of symmetry.

The Limit Forms.

The general form for special positions of the faces passes into limit forms. Six suppositions may be made each of which corre-

sponds to a limit-form. Denoting infinity by ∞ in Weiss symbols and by i in Dana we have :

	Weiss.	Dana.	Miller.
Each face parallel to two axes.			
1. Cube.	$a : \infty a : \infty a$	$i - i$	$\{100\}$
Each face parallel to one axis.			
2. Dodecahedron.	$a : a : \infty a$	I	$\{110\}$
3. Tetrahexahedron.	$a : na : \infty a$	$i - n$	$\{hk0\}$
Each face intersects all axes.			
4. Octahedron.	$a : a : a$	1.	$\{111\}$
5. Trigonal Trisoctahedron.	$a : a : ma$	m	$\{hhl\}$
6. Tetragonal Trisoctahedron.	$a : ma : ma$	$m - m$	$\{hkk\}$

The Six Limit Forms in Detail.

1. The Cube.—$a : \infty a : \infty a$; $i - i$; $\{100\}$.

Composed of six faces, Fig. 29, each parallel to two axes, all diedral and plane angles being right angles. The commonest of all crystal forms. In the ideal forms the faces are squares.

Fig. 29.

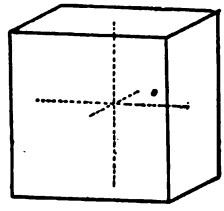
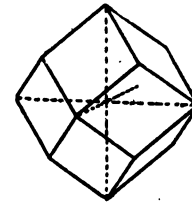


Fig. 30.



2. The Dodecahedron.—$a : a : \infty a$; i; $\{110\}$.

Composed of twelve faces, Fig. 30, each parallel to one axis and cutting the others at equal distances. In the ideal form each face is a rhombus.

Angles between adjacent faces 120°, between alternate faces 90°. The plane angles between edges are equal to the interfacial angles of the octahedron, *i. e.*, 109° 28′ 16″ and 70° 31′ 44″.

3. Tetrahexahedron.—$a : na : \infty a$; $i - n$; $\{hk0\}$.

Composed of twenty-four faces, Fig. 31, each parallel to one axis

Fig. 31.

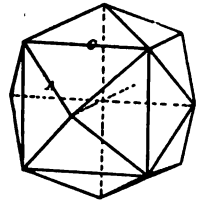
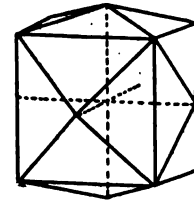


Fig. 32.



and cutting the other two unequally in distances bearing a simple ratio to each other. In the ideal forms the faces are equal isosceles triangles.

Fig. 31 shows $a : 2a : \infty a$ for which $A = C = 143° 8'$; Fig. 32 shows $a : 3a : \infty a$ for which $A = 154° 9'$, $C = 126° 52'$.

4. THE OCTAHEDRON.—$a : a : a$; 1; $\{111\}$

Composed of eight faces, Fig. 33, each cutting the three axes at equal distances. In the ideal form the faces are equilateral triangles.

The angles are 109° 28′ 16″ between adjacent faces and 70° 31′ 44″ between alternate faces.

The alternate edges are at right angles and the adjacent edges at 60°.

FIG. 33.

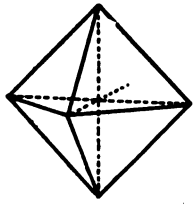
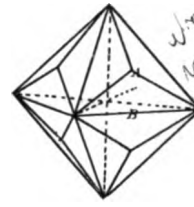


FIG. 34.



5. TRIGONAL TRISOCTAHEDRON.—$a : a : ma$; m; $\{hhl\}$.

Composed of twenty-four faces, Fig. 34, each cutting two axes at equal distances, the third axes at some longer distance a simple multiple of the others. In the ideal forms the faces are isosceles triangles.

For $m = 2$, $A = 152° 44'$, $B = 141° 3\frac{1}{2}'$. For $m = 3$, $A = 142° 8'$, $B = 153° 28\frac{1}{2}'$.

6. TETRAGONAL TRISOCTAHEDRON.—$a : ma : ma$; $m - m$; $\{hkk\}$.

Composed of twenty-four faces, each cutting two axes equally and the third in some shorter distance bearing a simple ratio to the others. In the ideal form the faces are trapeziums.

FIG. 35.

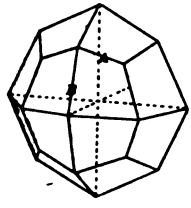


FIG. 36.

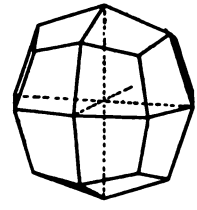


Fig. 35 shows $a : 2a : 2a$ for which $A = 146° 27'$; $B = 131° 59'$. Fig. 36 shows $a : 3a : 3a$ for which $A = 129° 31'$; $B = 144° 44'$.

Combinations in the Hexoctahedral Class.

The most frequently occurring forms are the cube a, the octahedron p, the dodecahedron d, and the tetragonal trisoctahedron $n = a : 2a : 2a$. The other forms usually occur modifying these.

FIG. 37.

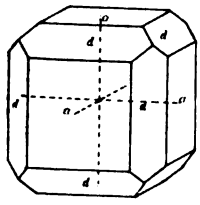


FIG. 38.

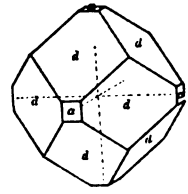
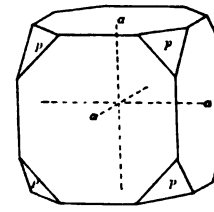


FIG. 39.



The cube a and dodecahedron d, Figs. 37, 38 are combined in crystals of fluorite, argentite and cuprite. The cube and octahe-

FIG. 40.

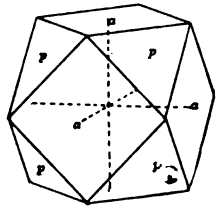


FIG. 41.

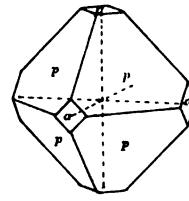
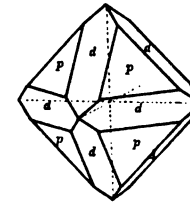


FIG. 42.



dron p, Figs. 39, 40 and 41, are very frequently combined in fluorite, pyrite, galenite, silver, sylvite and many other minerals. The

FIG. 43.

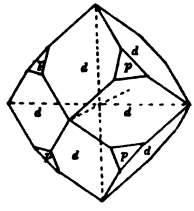


FIG. 44.

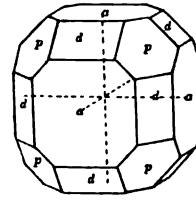
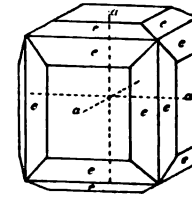


FIG. 45.



octahedron, p, and dodecahedron, d, Figs. 42 and 43, are frequently found in spinel, magnetite, franklinite and cuprite, while the three together, cube, dodecahedron, and octahedron, Fig. 44, occur in

smaltite, galenite and fluorite. The tetrahexahedron e, $(a : 2a : \infty a)$ is found with the cube in fluorite, Fig. 45. The tetragonal

FIG. 46.

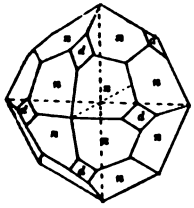


FIG. 47.

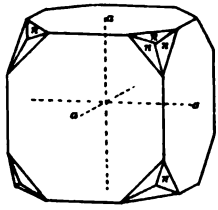
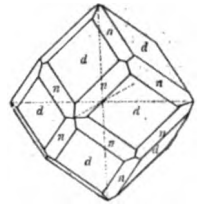


FIG. 48.



trisoctahedron n, $(a : 2a : 2a)$ is common in analcite, garnet and amalgam, either combined with the dodecahedron, Figs. 46 and 48, or with the cube, Fig. 47.

FIG. 49.

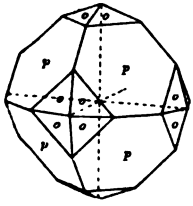


FIG. 50.

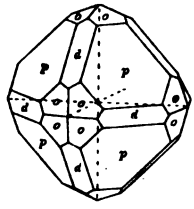
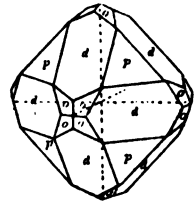


FIG. 51.



Another tetragonal trisoctahedron o, $(a : 3a : 3a)$ occurs in spinel and magnetite either with the octahedron, Fig. 49, or with both octahedron and dodecahedron, Figs. 50 and 51.

FIG. 52.

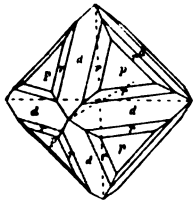


FIG. 53.

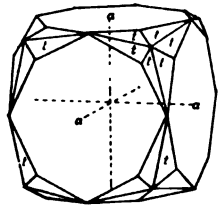


FIG. 54.

The trigonal trisoctahedron r, $(a : a : 2a)$ occasionally occurs, especially in galenite and magnetite, combined with octahedron and dodecahedron, Fig. 52. The hexoctahedron t, $(a : 2a : 4a)$ occurs modifying cubes of fluorite, Fig. 53, and another hexoctahedron s, $(a : \frac{3}{2}a : 3a)$ occurs in garnet, Fig. 54.

HEXTETRAHEDRAL CLASS. 31.

No. 2. Tetrahedral Hemihedry, *Liebisch.* No. 3. Tetrahedral Group, *Dana.*

In this class of isometric forms, to which crystals of the diamond, tetrahedrite, sphalerite and boracite belong, the shaded planes of Fig. 24 are no longer planes of symmetry, and the symmetry is restricted to the diagonal planes shown in Fig. 55 and to the axes formed by their intersection.

THE GENERAL FORM OR HEXTETRAHEDRON.

Weiss, $a : na : ma$; Dana, $m - n$; Miller $\{hkl\}$.

Composed of twenty-four faces each cutting the three axes in three different, but simply proportionate, distances. In the ideal forms the faces are scalene triangles.

FIG. 55.

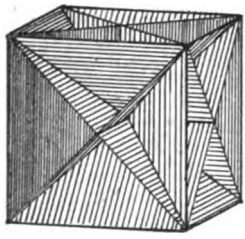


FIG. 56.

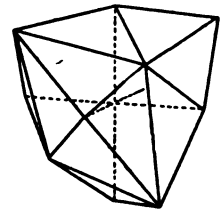
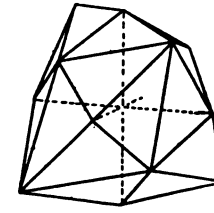


FIG. 57.



In a manner precisely similar to that followed on p. 13 it may be shown that if one face of the general form occurs twenty-four must, and according to the position of the first face the form will be that shown in Fig, 56, usually called the positive form, or that shown in Fig. 57, called the negative form. The positions of the crystallographic axes are indicated.

The Limit Forms.

Three of the six limit forms are geometrically identical with the forms of the preceding class, namely,

1. THE CUBE. Fig. 29.
2. THE DODECAHEDRON. Fig. 30.
3. THE TETRAHEXAHEDRON. Figs. 31 and 32.

The geometrically new forms are :

4. THE TETRAHEDRON.—$a : a : a$; 1; $\{111\}$.

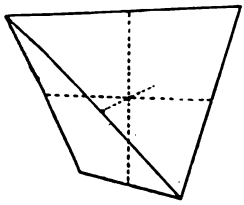
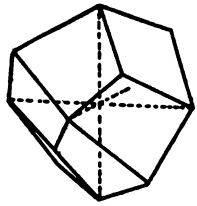
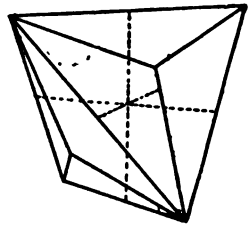
Composed of four faces, Fig. 58, each cutting the three axes at equal distances. In the ideal form the faces are equilateral triangles.

All interfacial angles are 70° 31′ 44″ and all plane angles between edges are 60°.

5. TETRAGONAL TRISTETRAHEDRON.—$a : a : ma$; m ; $\{hhl\}$.

Composed of twelve faces, Fig. 59, each cutting two axes equally and the third in some longer distance a simple multiple of the others. In the ideal form the faces are trapeziums.

FIG. 58. FIG. 59. FIG. 60.

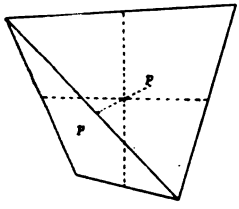
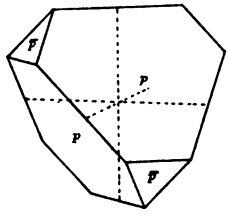
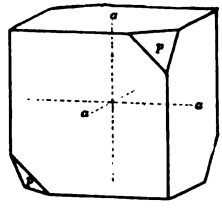
6. TRIGONAL TRISTETRAHEDRON.— $a : ma : ma$; $m - m$; $\{hkk\}$.

Composed of twelve faces, Fig. 60, each cutting two axes equally and the third in some shorter distance bearing a simple ratio to the others. In the ideal form the faces are isosceles triangles.

Combinations in the Hextetrahedral Class.

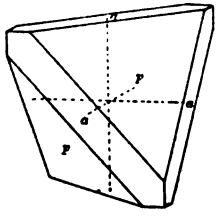
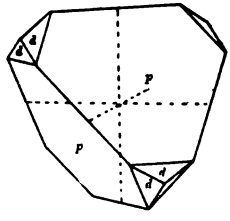
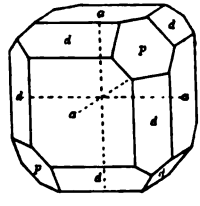
The characteristics of the crystals of this group are best shown

FIG. 61. FIG. 62. FIG. 63.

in the combination forms, since the simple forms are comparatively rare and the predominating form is frequently the cube.

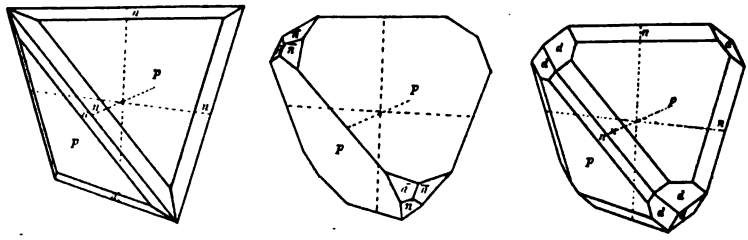
FIG. 64. FIG. 65. FIG. 66.

The simple tetrahedron p, Fig. 61, and the combination of the positive and negative tetrahedrons, Fig. 62, occur as crystals of sphal-

erite and tetrahedrite. The combination of the tetrahedron and cube *a*, Fig. 63 and 64, is common in boracite and pharmacosiderite. The tetrahedron with the dodecahedron *d*, Fig. 65, occurs in tetrahedrite, and with both cube and dodecahedron, Fig. 66, in boracite.

FIG. 67. FIG. 68. FIG. 69.



Figs. 67, 68, 69 and 70 are all crystals of tetrahedrite. Fig. 67 is the tetrahedron with the trigonal tristetrahedron *n*, $(a : 2a : 2a)$. In Fig. 68 the negative form of *n* occurs and in Fig. 69 the dodecahedron *d* is an additional form.

FIG. 70. FIG. 71. FIG. 72.

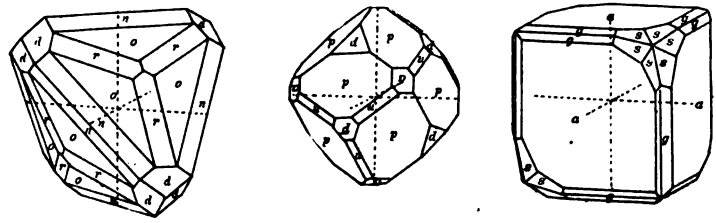


Fig. 70 is more complex and includes the dodecahedron *d*, the tetragonal tristetrahedron *r*, $(a : a : 2a)$ and the trigonal tristetrahedrons *o*, $(a : 3a : 3a)$ and *n*, $(a : 2a : 2a)$. Fig 71 represents a crystal of boracite with the cube, dodecahedron, both tetrahedrons and the trigonal tristetrahedron *n*, while Fig. 72 shows the hextetrahedron *s*, $(a : \frac{3}{2}a : 3a)$ combined with the cube and tetrahexahedron *g*, $(a : \frac{3}{2}a : \infty a)$.

CLASS OF THE DIPLOID. 30.

No. 4. Pentagonal Hemihedry, *Liebisch*. No. 2. Pyritohedral Group, *Dana*.

Crystals of the common mineral pyrite and of the minerals cobaltite and smaltite have the symmetry shown in Fig. 73.

THE GENERAL FORM OR DIPLOID.

Weiss, $a : na : ma$; Dana, $m - n$; Miller, $\{ hkl \}$.

Composed of twenty-four faces each cutting the three axes in three different, but simply proportionate, distances. In the ideal form the faces are trapeziums. Fig. 74 shows the plus form. Fig. 75 the corresponding minus form.

FIG. 73.

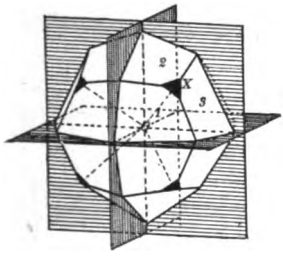


FIG. 74.

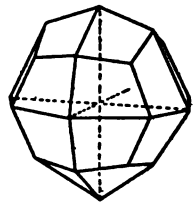
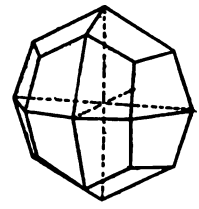


FIG. 75.



That it requires twenty-four faces to satisfy the symmetry of the class may be seen from Fig. 73. For any face 1, must, because of the trigonal axis OX, be accompanied by the faces 2 and 3, and because of the shaded planes of symmetry a similar three must occur in each octant.

The Limit Forms.

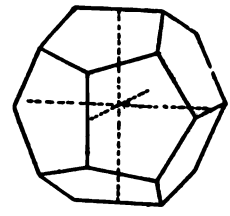
Five of the six limit forms are geometrically identical with forms already described namely :

1. THE CUBE, Fig. 29.
2. THE DODECAHEDRON, Fig. 30.
4. THE OCTAHEDRON, Fig. 33.
5. TRIGONAL TRISOCTAHEDRON, Fig. 34.
6. TETRAGONAL TRISOCTAHEDRON, Fig. 35.

The new form is :

3. PYRITOHEDRON. — $a : na : \infty a$; $i - n$; $\{hk0\}$.

FIG. 76.



Composed of twelve faces, Fig. 76, each parallel to one axis and cutting the other two unequally in distances bearing a simple ratio to each other. In the ideal forms the faces are pentagons.

Combinations in the Class of the Diploid.

These combinations greatly resemble those of the hexoctahedral class because five of the seven forms occur in both, and the other two are parallel faced.

FIG. 77. FIG. 78. FIG. 79.

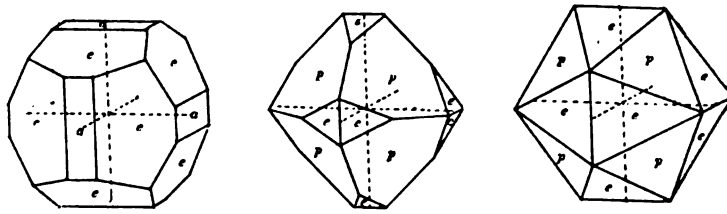


Fig. 77 shows the pyritohedron e, $(a : 2a : \infty a)$ with the cube a. Figs. 78 and 79 show the same form with the octahedron p.

FIG. 80. FIG. 81. FIG. 82.

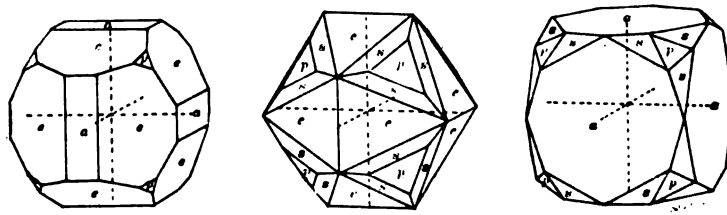


Fig. 80 shows the three forms combined. Fig. 81 shows the same pyritohedron e and octahedron p combined with the diploid s, $(a : \frac{3}{2}a : 3a)$ and Fig. 82 shows this diploid with the cube and octahedron.

Two classes of lower symmetry exist but need not be described here as no common minerals are known to occur in one and the minerals referred to the other are so referred rather by virtue of etching tests than from the shape of the common crystals.

CHAPTER III.

TETRAGONAL SYSTEM.

In all Tetragonal* forms the crystallographic axes can be chosen at right angles to each other, so that two will be interchangeable.

In models and drawings representing ideal forms the interchangeable axes are equal in length and the third axes is longer or shorter but *never a simple multiple* of the lengths of the interchangeable axes. In real crystals the interchangeable axes are directions surrounded by exactly the same number of faces and with corresponding faces at the same angles. The grouping of faces about the third axis is not the same as to angles and not necessarily the same as to number of faces.

Conventionally the crystal is placed so that the two interchangeable axes are horizontal and the third axis vertical. The former are known as the basal or *a* axes, the latter as the vertical or *c* axis.

Groups or Classes of Forms.

According to the number and arrangement of the planes and axes of symmetry, tetragonal crystal forms have been divided into seven classes. Of these two are unknown among crystals of minerals and two are represented by one mineral each. The remaining classes are described following the same general method as in the isometric.

Series.

Just as in the isometric system a substance can only occur in forms of one class and in forms of *one series* in that class. This has been explained generally upon page 8, but warrants here a more detailed explanation.

In the isometric system all three axes were interchangeable, that is, all were surrounded by the same number of faces at the same

* Also called Pyramidal, Viergliedrige, Zwei-und-einaxige, Monodimetric, Quadratic and Dimetric.

angles, and these angles were always such that the three intercepts of any face were simple multiples of each other, such as $a : 2a : 3a$.

In the tetragonal system, however, while the intercepts of any face upon the two interchangeable axes are simple multiples of each other, the intercept of this face with the third axis will *not be* a simple multiple of either of the other intercepts and furthermore this complex relation will be different *for every form upon each different substance.*

Experience, however, has shown that a perfectly exact relation exists between the different complex values for the third intercept obtained from different faces *of the same substance* such that this intercept for any one face is always a simple multiple or simple fractional part of the corresponding intercept for any other face.

Advantage is taken of this to secure simple instead of complex symbols as follows: Some prominent face which must intersect the vertical and at least one of the basal axes is chosen as the unit face, and its symbol is said to be $a : na : c$ in which a is the shorter horizontal intercept, c is the vertical intercept and n is necessarily a simple number or infinite. This ratio is always reduced until a is unity, that is, may be of such a form as $a : na : c = 1 : 2 : 1.073$.

If now the intercepts of *any* other face of a crystal *of the same substance* are obtained and reduced so that the shorter horizontal intercept is unity, the face may be expressed by the symbol $a : n'a : mc$ in which both m and n' are simple numbers or infinite.

For example, by calculation the relative intercepts of the common forms of zircon, see Figs. 91 to 94, p. 27, are $p = 1 : 1 : 0.64$ which may be denoted by $a : a : c$, then *in comparison* the face m with intercepts $1 : 1 : \infty$ is $a : a : \infty c$; the face a with intercepts $1 : \infty : \infty$ is $a : \infty a : \infty c$; the face u with intercepts $1 : 1 : 1.92$ is $a : a : 3c$ and the face x with intercepts $1 : 3 : 1.92$ is $a : 3a : 3c$.

CLASS OF THE DITETRAGONAL PYRAMID. 15.

No. 18. Holohedry, *Liebisch.* No. 6. Normal, *Dana.*

Symmetry of the Class.

As shown in Fig. 83 forms in this class are symmetrical to one horizontal plane and to four vertical planes at forty-five degrees to each other. The intersections of these planes with each other are axes of symmetry and of these CC is an axis of tetragonal symmetry. CC and either pair of alternate horizontal axes may be chosen as crystal axes.

THE GENERAL FORM OR DITETRAGONAL PYRAMID.

Weiss, $a : na : mc$; Dana, $m - n$; Miller, $\{ hkl \}$.

Composed of sixteen faces, Fig. 84, each cutting the two basal axes at unequal but simply proportionate distances, and the vertical axis at a distance *not* simply proportionate to the other distances. In the ideal forms the faces are scalene triangles.

FIG. 83.

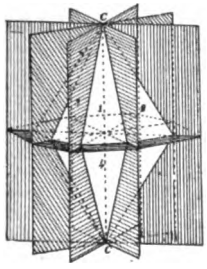
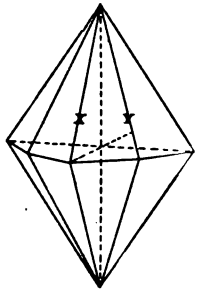


FIG. 84.



The values of m and n may be determined from any two diedral angles. For X and Y the equations are :

$$n = 1 + \frac{\cos \frac{1}{2} Y \times 1.4142}{\cos \frac{1}{2} X}, \quad n \cot \tfrac{1}{2} X = \sin a, \quad \tan a = mc.$$

That sixteen such faces are needed to satisfy the symmetry is seen in Fig. 83. If the face 1 occurs, the planes of symmetry make necessary the occurrence of faces 2, 3, and 4, and each of these must have on each side and below a corresponding plane and so on ; or sixteen faces in all.

Limit Forms.

The general form, for special positions of the faces, passes into limit forms. Assuming the conventional position of the axes with the axis c vertical these limit positions are :

Each face horizontal.	WEISS.	DANA.	MILLER.
1. BASAL PINACOID.	$\infty a : \infty a : c$	0	{ 001 }
Each face vertical.			
2. PRISM OF SECOND ORDER.	$a : \infty a : \infty c$	$i - i$	{ 100 }
3. PRISM OF FIRST ORDER.	$a : a : \infty c$	I	{ 110 }
4. DITETRAGONAL PRISM.	$a : na : \infty c$	$i - n$	{ hk0 }
Each face inclined.			
5. PYRAMID OF SECOND ORDER.	$a : \infty a : mc$	$m - i$	{ h0l }
6. PYRAMID OF FIRST ORDER.	$a : a : mc$	m	{ hhl }

The Limit Forms in Detail.

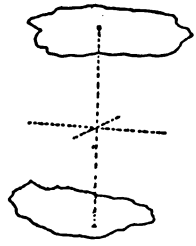
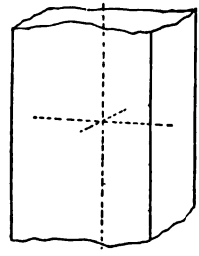
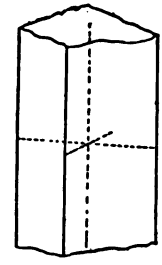
1. BASAL PINACOID.—$\infty a : \infty a : c$: 0, {001}.

Composed of two faces, Fig. 85, each parallel to both the basal axes.

2. PRISM OF SECOND ORDER.—$a : \infty a : \infty c$; $i - i$; {100}.

Composed of four faces, Fig. 86, each parallel to the vertical axis and to one basal axis. The interfacial angles are 90°.

FIG. 85. FIG. 86. FIG. 87.

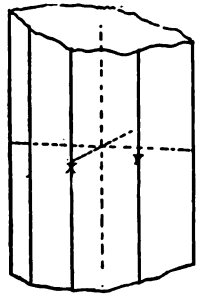
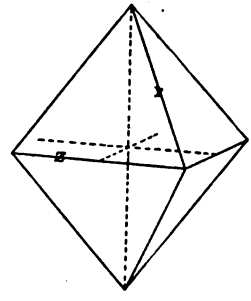
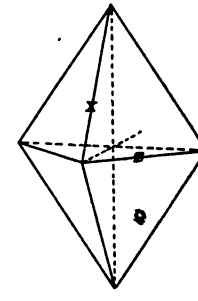
3. PRISM OF THE FIRST ORDER.—$a : a : \infty c$; I; {110}.

Composed of four faces, Fig. 87, each parallel to the vertical axis and cutting the basal axes at equal distances from the centre. The interfacial angles are 90°.

4. DITETRAGONAL PRISM.—$a : na : \infty c$; $i - n$; {hk0}.

Composed of eight faces, Fig. 88, each parallel to the vertical axis and cutting the two basal axes in distances unequal but simply proportionate.

FIG. 88. FIG. 89. FIG. 90.

The value of n may be determined, Fig. 88, by the equations:

$$n = \tan \tfrac{1}{2} X, \text{ or } n = \tan (135° - \tfrac{1}{2} Y.)$$

5. PYRAMID OF SECOND ORDER.—$a : \infty a : mc$; $m - i$; $\{h\,o\,l\}$.

Composed of eight faces, Fig. 89, each parallel to one basal axis, and cutting the other basal axis and the vertical axis at either unit distances or simple multiples of these. In ideal forms the faces are isosceles triangles.

The value of *mc* may be determined by the following equations, Fig. 89:

$$\cos \tfrac{1}{2}Y \times 1.4142 = \sin a, \quad \tan \tfrac{1}{2}Z = \tan a, \quad mc = \tan a.$$

6. PYRAMID OF FIRST ORDER.—$a : a : mc$; m; $\{hhl\}$.

Composed of eight faces, Fig. 90, each cutting the basal axes at equal distances, and the vertical axis at some distance *not a simple multiple* of the basal intercepts. In the ideal forms the faces will be isosceles triangles.

The value of *mc* may be determined, Fig. 90, by the following equations:

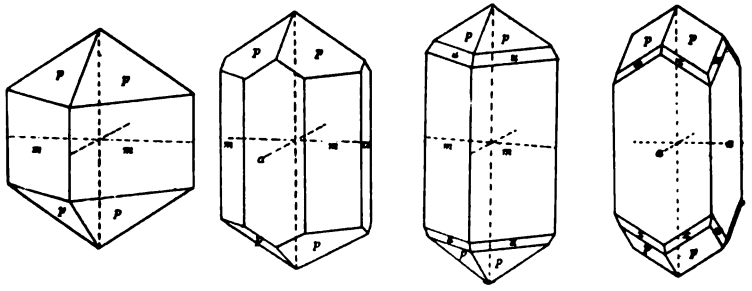
$$mc = \tan \tfrac{1}{2}Z \times .7071, \text{ or } \sin a = \cot \tfrac{1}{2}X, \quad mc = \tan a.$$

Series and Combinations in the Class of Ditetragonal Pyramid.

It is only by considering the forms in series, that is the forms of each substance separately, that a clear idea is obtained as to the pyramidal forms. The prismatic forms and the basal pinacoid are alike for all substances crystallizing in the class, but the pyramids vary in shape and angle with the relative lengths of *mc* and *a*. Though as explained, p. 24, the pyramids which occur upon crystals of *any one substance* are definitely related in axial intercepts and usually very limited in number.

The common forms of certain minerals in this class have therefore been assembled here.

FIG. 91. FIG. 92. FIG. 93. FIG. 94.



Zircon.—Axes $a : c = 1 : 0.640$.

Fig. 91 shows the common association of unit pyramid p and unit prism m. In Fig. 92 these two forms are combined with the prism of the second order a and in Fig. 93 with the pyramid $u = (a : a : 3c)$. Fig. 94 shows the union of second order prism, unit pyramid and ditetragonal pyramid $x = (a : 3a : 3c)$.

FIG. 95.

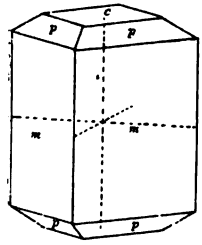


FIG. 96.

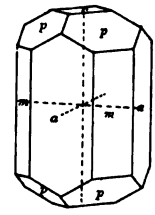
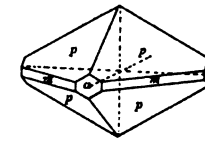


FIG. 97.



Vesuvianite.—Axes $a : c = 1 : 0.537$.

The unit pyramid in vesuvianite is a little flatter than in zircon but not much, hence in the drawings there is little apparent difference between the pyramid angles in Fig. 91 and Fig. 97. The relative development of faces, or crystal habit, is, however, markedly different, as is at once apparent on comparing the two series of common crystals.

Fig. 95 shows the combination of unit pyramid p, unit prism m and basal pinacoid c, Fig. 96 shows these three forms combined with the prism of the second order a and Fig. 97 shows the two prisms and the unit pyramid.

FIG. 98.

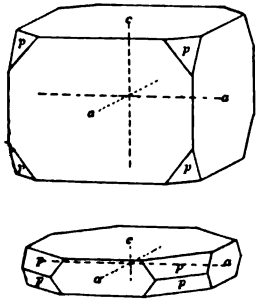


FIG. 100.

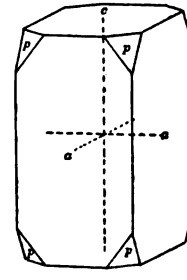


FIG. 101.

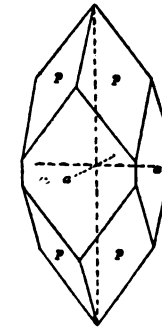


FIG. 99.

Apophyllite.—Axes $a : c = 1 : 1.252$.

As indicated by the ratios of a to c the unit pyramid of this mineral is much more acute than in zircon and vesuvianite, this is clearly apparent in Fig. 101. The figures also illustrate very well the possibility of great differences in habit without any difference in occurring forms, thus Figs. 98, 99 and 100 are all combinations the unit pyramid p, basal pinacoid c and second order prism a. In Fig. 101 the basal pinacoid does not occur.

FIG. 102.

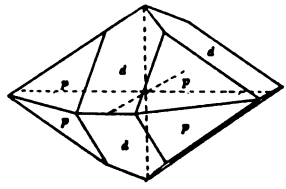
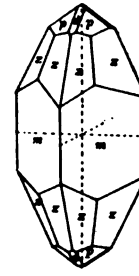


FIG. 103.



Cassiterite.—Axes $a : c = 1 : 0.6723$.

In this the ratio of a to c is closely as in zircon but the common association is now the unit pyramid p with the second order pyramid d as shown in Fig. 102.

In Fig. 103 these forms occur with a ditetragonal pyramid $z = (a : \frac{3}{2}a : 3c)$ and the unit prism m.

CLASS OF THE THIRD ORDER PYRAMID. 13.

No. 21—Pyramidal Hemihedry, *Liebisch.* No. 8—Pyramidal Group, *Dana.*

Certain crystals of the minerals scheelite and wernerite are symmetrical to one horizontal plane and one vertical tetragonal axis only.

FIG. 104.

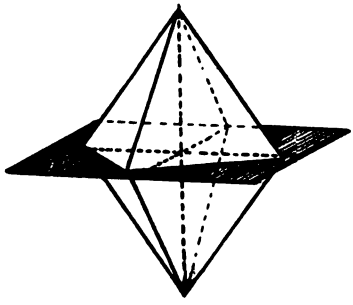


FIG. 105.

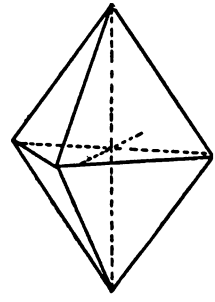
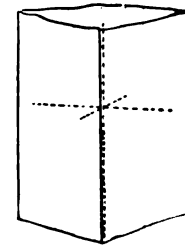


FIG. 106.



THE GENERAL FORM OR THIRD ORDER PYRAMID.—Weiss, $a : na : mc$; Dana, $m - n$; Miller, $\{hkl\}$.

Composed of eight faces, Fig. 105, each cutting the two basal axes at unequal but simply proportionate distances, and the vertical axis at a distance *not* simply proportionate to the other distances. In the ideal forms the faces are isosceles triangles.

That eight such faces satisfy the symmetry is shown by Fig. 104. Any occurring face must, because of the vertical axis of tetragonal symmetry, occur with three other faces above the horizontal axes, and because of the horizontal plane of symmetry each of these must be accompanied by a face below the plane.

The Limit Forms.

Five of the limit forms are geometrically like forms already described, namely:

1. BASAL PINACOID. Fig. 85.
2. PRISM OF SECOND ORDER. Fig. 86.
3. PRISM OF FIRST ORDER. Fig. 87.
5. PYRAMID OF SECOND ORDER. Fig. 89.
6. PYRAMID OF THE FIRST ORDER. Fig. 90.

The geometrically new form is:

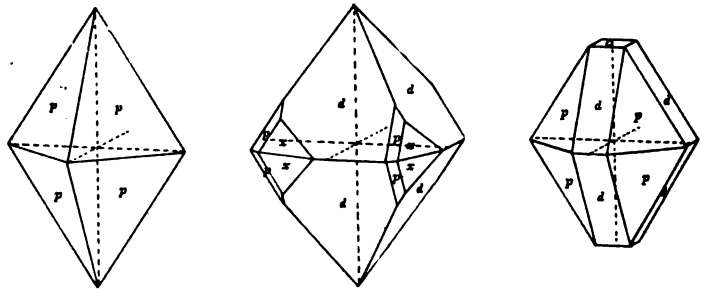
4. PRISM OF THIRD ORDER.—$a : na : \infty c$; $i - n$; $\{hk0\}$.

Composed of four faces, Fig. 106, each parallel to the vertical axis and cutting the two basal axes in distances unequal but simply proportionate.

Series and Combinations in the Class of Third Order Pyramid.

In this class the simple forms are all of apparently higher symmetry than the class, but in their combinations the true symmetry is sometimes to be recognized.

FIG. 107. FIG. 108. FIG. 109.



Scheelite.—Axes $a : c = 1 : 1.535$.

Thus Fig. 107 is only the unit pyramid p and Fig. 109 is the

unit pyramid with the pyramid of second order d and the basal pinacoid, but in Fig. 108 the planes $x = (a : 3a : 3c)$, of the pyramid of third order settle the symmetry definitely.

SCALENOHEDRAL CLASS. 11.

No. 23. Sphenoidal Hemihedry, *Liebisch*. No. 10. Sphenoidal Group, *Dana*.

This class bears about the same relation to the preceding class that the hextetrahedral class, p. 18, does to the hexoctahedral, p. 12. The principal mineral of the group is chalcopyrite. The planes and axes of symmetry are shown in Fig. 110. The axes of symmetry are chosen as the crystal axes.

FIG. 110.

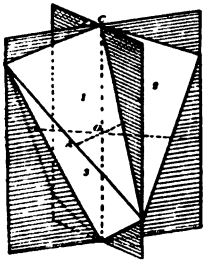


FIG. 111.

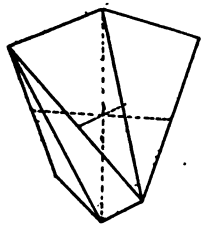
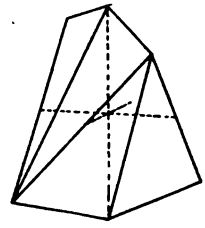


FIG. 112.



THE GENERAL FORM OR SCALENOHEDRON.

Weiss, $a : na : mc$; Dana, $m - n$; Miller, $\{ hkl \}$.

Composed of eight faces, each cutting the two basal axes at unequal but simply proportionate distances and the vertical axis at a distance *not* simply proportionate to the others. In the ideal form the faces are scalene triangles.

That eight such faces are necessary to satisfy the symmetry of the class may be seen in Fig. 110. If a face 1, of the general symbol $a : na : mc$ occurs the face 2 must occur on the other side of the plane of symmetry and the face 3 must occur because OA is an axis of binary symmetry. Continuing in this way eight faces result which may be as in Fig. 111, the positive form, or Fig. 112, the negative form, according to the position of the first face.

THE SIX LIMIT FORMS.

Five of the forms are geometrically identical with the forms of the preceding class, namely.

1. BASAL PINACOID. Fig. 85.
2. PRISM OF SECOND ORDER. Fig. 86.
3. PRISM OF FIRST ORDER. Fig. 87.

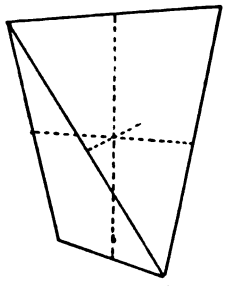
4. DITETRAGONAL PRISM. Fig. 88.

5. PYRAMID OF SECOND ORDER. Fig. 89.

The geometrically new shape is :

6. TETRAGONAL SPHENOID.—$x : a : mc$; m ; $\{hhl\}$.

FIG. 113.



Composed of four faces, Fig. 113, each cutting the basal axes at equal distances, and the vertical axis at some distance *not a simple multiple* of the basal intercepts. In the ideal form the faces will be isosceles triangles.

Series and Combinations in the Scalenohedral Class.

Chalcopyrite.—Axes $a : c = 1 : 0985$.

Fig. 114 shows the positive and negative unit sphenoid p and $\bar{p}$ with the second order pyramid $e = (a : \infty a : 2c)$. Fig. 115 shows a sphenoid $o = (a : a : \frac{7}{4}c)$ with a scaleno-

FIG. 114.

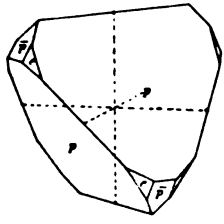


FIG. 115.

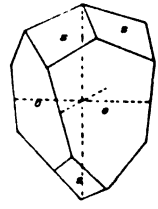
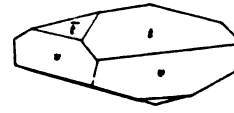


FIG. 116.



hedron $s = (a : 2a : c)$. Fig. 116 shows a sphenoid $v = (a : a : 4c)$ with the positive and negative forms of a much flatter sphenoid $t = (a : a : \frac{1}{4}c)$.

As stated, p. 23, four other classes of symmetry are recognized among tetragonal crystals, phosgenite is supposed to belong to one and wulfenite to another while the other two have no representatives among the common minerals.

CHAPTER IV.

HEXAGONAL SYSTEM.*

Hexagonal crystals in all characters except shape so closely resemble tetragonal crystals as to be grouped with them. In shape there are also points of great similarity.

It has been found most convenient† to refer all hexagonal forms to *four* crystallographic axes, one vertical and at right angles to the others, three horizontal and interchangeable and at sixty degrees to each other.

Conventionally the vertical axis is the *c* axis and the interchangeable axes are the basal or *a* axes, and the crystal is always held so that the *c* axis is vertical and one of the *a* axes extends from right to left.

Classes of Forms.

According to the number and arrangement of the planes and axes of symmetry hexagonal crystal forms have been divided into twelve classes of which four are not known to be represented among the crystals of minerals and two are each represented by a single species.

All that was said, p. 23, as to series may be repeated here without essential alteration.

CLASS OF THE DIHEXAGONAL PYRAMID. 27.

No. 6. Holohedral, *Liebisch*. No. 13. Normal Group, *Dana*.

Symmetry of the Class.

Very few minerals crystallize in forms of this highest class of hexagonal symmetry. Beryl furnishes the best example. As shown in Fig. 117 the forms are symmetrical to one horizontal plane and to six vertical planes at thirty degrees to each other as well as to the lines of intersection of these planes.

---

* Also called Rhombohedral, Sechsgliedrige, Drei-und-Einaxige and Monotrimetric.

† A portion of the hexagonal system the "rhombohedral division" is referred by Miller to three oblique axes and this method is followed by Groth. Even when four axes are used the value of the third horizontal intercept can always be calculated from the other two.

FIG. 117.

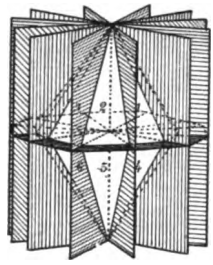
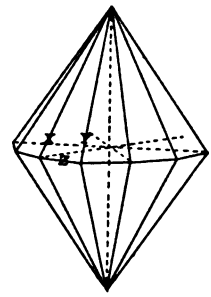


FIG. 118.



THE GENERAL FORM OR DIHEXAGONAL PYRAMID.

Weiss, $na : \frac{n}{n-1} a : a : mc$; Dana, $m - n$; Miller, $\{hk\bar{l}i\}$.

Composed of twenty-four faces, Fig. 118, each of which cuts the three basal axes at unequal distances, simple multiples of each other; and the vertical axis at some distance *not* simply related to the others. In the ideal form the faces are scalene triangles.

That twenty-four such faces are needed to satisfy the symmetry of the class is readily seen in Fig. 117. Any face 1 reflected in the vertical planes becomes 12 faces and each of these reflected in the horizontal plane conditions another.

The values of n and of mc may be found by the following equations. See Fig. 118.

Given X and Z, $\cos \nu = \frac{\cos \frac{1}{2}X}{\sin \frac{1}{2}Z}$; $n = \frac{1}{2} + \tan (\nu - 30°) \times .866$;

$$mc = \tan \tfrac{1}{2}Z \sin \nu.$$

Given Y and Z, $\cos \delta = \frac{\cos \frac{1}{2}Y}{\sin \frac{1}{2}Z}$; $n = \frac{1}{2} + \tan (120° - \delta) \times .866$;

$$mc = \tan \tfrac{1}{2}Z \sin (150° - \delta).$$

The Limit Forms.

The general form for special positions of the faces passes into certain limit forms. With the conventional position of the axes the following positions correspond to limit forms:

Each face horizontal.	WEISS.	DANA.	MILLER.
1. BASAL PINACOID.	$\infty a : \infty a : \infty a : c$	0	$\{0001\}$
Each face vertical.			
2. HEX. PRISM FIRST ORDER.	$a : \infty a : a \infty c$	I,	$\{10\bar{1}0\}$
3. HEX. PRISM SECOND ORDER.	$2a : 2a : a : \infty c$	$i - 2$	$\{11\bar{2}0\}$
4. DIHEXAGONAL PRISM.	$na : \frac{n}{n-1} a : a : \infty c$	$i - n$	$\{hk\bar{l}0\}$
Each face oblique.			
5. HEX. PYRAMID FIRST ORDER.	$a : \infty a : a : mc$	m	$\{ho\bar{h}i\}$
6. HEX. PYRAMID SECOND ORDER.	$2a : 2a : a : mc$	$m - 2$	$\{hh2\bar{h}i\}$

The Limit Forms in Detail.

1. BASAL PINACOID.— $\infty a : \infty a : \infty a : c$; 0 ; $\{0001\}$.

Composed of two faces, Fig. 119, each parallel to the three basal axes.

2. HEXAG. PRISM OF FIRST ORDER.—$a : \infty a : a : \infty c$; I ; $\{10\bar{1}0\}$.

Composed of six faces, Fig. 120, each parallel to the vertical axis and to one basal axis and cutting the other two basal axes at equal distances.

FIG. 119.

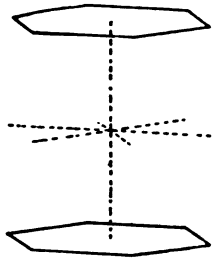


FIG. 120.

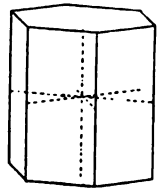
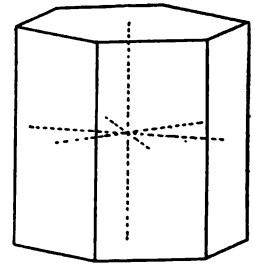


FIG. 121.

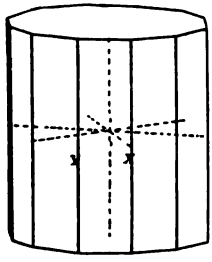


3. HEXAG. PRISM OF SECOND ORDER.—$2a : 2a : a : \infty c$; $i - 2$; $\{11\bar{2}0\}$.

Composed of six faces, Fig. 121, each parallel to the vertical axis and cutting one basal axis at a certain distance and the other two at *twice* that distance.

4. DIHEXAGONAL PRISM.—$na : \frac{n}{n-1} a : a : \infty c$; $i - n$; $\{hk\bar{i}0\}$.

FIG. 122.



Composed of twelve faces, Fig. 122, each parallel to the vertical axes and cutting all three basal axes at unequal distances which are simple multiples of each other.

The value of n may be calculated by the following equations, Fig. 122.

$$\tan \tfrac{1}{2}X \times .5773 = \frac{n}{2-n}, \text{ or } \tan \tfrac{1}{2}Y \times 1.732 = \frac{n+1}{n-1}.$$

5. HEXAG. PYRAMID OF FIRST ORDER.—$a : \infty a : mc$; m ; $\{ho\bar{h}i\}$.

Composed of twelve faces, Fig. 123, each parallel to one basal axis, cutting the other two basal axes at equal distances, and

cutting the vertical axis at some distance *not* simple proportionate to the intercepts on the basal axes. In ideal forms the faces are isosceles triangles.

The value of mc may be found by the following equations, Fig. 123.

$$\tan \tfrac{1}{2}Z \times .866 = mc; \text{ or } \sin \alpha = \cot \tfrac{1}{2}X \times 1.732; \tan \alpha = mc.$$

FIG. 123.

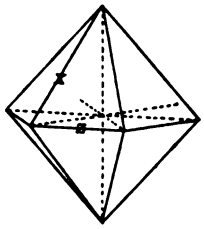
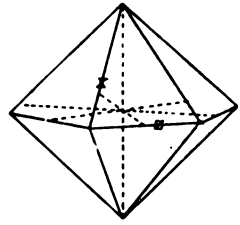


FIG. 124.



6. HEXAG. PYRAMID OF SECOND ORDER.—$2a : 2a : a : mc$; $m - 2$; $\{hh2\bar{h}i\}$.

Composed of twelve faces, Fig. 124, each cutting one basal axis at a certain distance, the other basal axes at *twice* that distance, and the vertical axis at some distance *not* simply proportionate to the others. In the ideal form the faces are isosceles triangles.

The value of mc may be calculated, Fig. 124, by the equations:

$$2 \cos \tfrac{1}{2}X = \sin \tfrac{1}{2}Z; \quad \tan \tfrac{1}{2}Z = mc.$$

Combinations of Forms in the Class of Dihexagonal Pyramid.

Beryl.—Axes $a : c = 1 : 0.499$

FIG. 125.

FIG. 126.

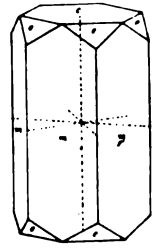
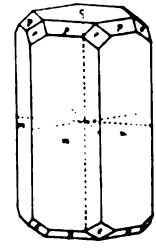


FIG. 127.



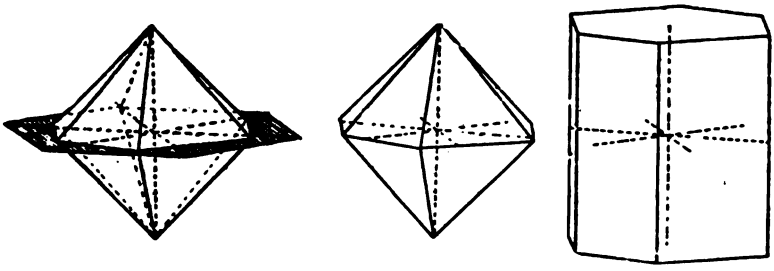
...ws the usual prism of first order m and basal pina-
...26 the second order pyramid $e = (2a : 2a : a : 2c)$
... 127 the unit pyramid p is also present.

CLASS OF THE THIRD ORDER PYRAMID. 25.

No. 9. Pyramidal Hemihedry, *Liebisch.* No. 15. Pyramidal Group, *Dana.*

Crystals of the minerals apatite and vanadinite are symmetrical only to one horizontal plane and one vertical hexagonal axis.

FIG. 128. FIG. 129. FIG. 130.



THE GENERAL FORM OR THIRD ORDER PYRAMID. — Weiss, $na : \frac{n}{n-1} a : a : mc$; Dana, $m-n$; Miller, $\{hkl\bar{i}\}$.

Composed of twelve faces, Fig. 129, each intersecting the vertical axis and also cutting all three basal axes at unequal distances which are simple multiples of each other.

That twelve such faces are necessary to satisfy the symmetry of the class, may be traced in Fig. 128. The resulting form is geometrically like the pyramids of first and second order, and is distinguishable only when combined with other forms.

The Limit Forms.

Five of the limit forms are geometrically like forms already described, namely;

1. BASAL PINACOID. Fig. 119.
2. HEXAGONAL PRISM OF FIRST ORDER. Fig. 120.
3. HEXAGONAL PRISM OF SECOND ORDER. Fig. 121.
5. HEXAGONAL PYRAMID OF FIRST ORDER. Fig. 123.
6. HEXAGONAL PYRAMID OF SECOND ORDER. Fig. 124.

The new form is:

4. HEXAGONAL PRISM OF THIRD ORDER.—$na : \frac{n}{n-1} a : a : \infty c$; $i-n$; $\{hk\bar{i}0\}$.

Composed of six faces, Fig. 130, each parallel to the vertical axis and cutting all three basal axes at unequal distances which are simple multiples of each other.

Combinations in the Class of the Third Order Pyramid.

Apatite.—Axes $a : c = 1 : 0.734$.

As in the corresponding tetragonal class it is only the occasional crystal that shows the symmetry by the position of its faces. Thus in the six figured crystals of apatite only Fig. 163 proves the true symmetry by the occurring faces.

FIG. 131.

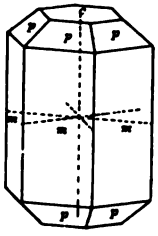


Fig. 132.

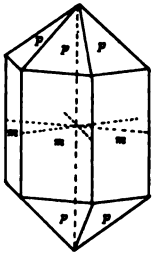


Fig. 133.

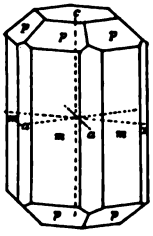


FIG. 134.

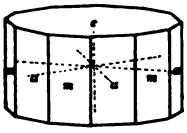


FIG. 135.

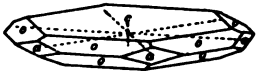
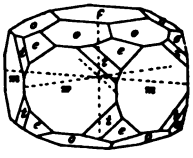


FIG. 136.



Figs. 131, 132, 133 and 134 show variations in habit in combinations of the unit pyramid p, basal pinacoid c and first and second order prisms, m and a. In Fig. 135 a flatter pyramid $o = (a : \infty a : a : \frac{1}{2} c)$ occurs with the basal pinacoid and second order prism, and in Fig. 136 a third order pyramid $t = (\frac{4}{3} a : 4a : a : 4c)$ occurs with the unit prism, basal pinacoid, pyramid of first order o and pyramid of second order $e = (2a : 2a : a : 2c)$.

Vanadinite.—Axes $a : c = 1 : 0.712$.

The usual combination, Fig. 137, is the prism m and base c, but

FIG. 137.

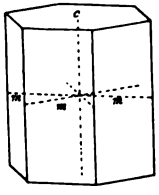
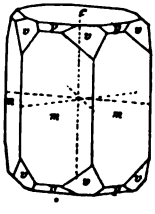


FIG. 138.



in Fig. 138, there is shown also the unit pyramid p, and a third order pyramid v, $(\frac{3}{2} a : 3 a : a : 3c)$.

SCALENOHEDRAL CLASS. 31.

No. 13. Rhombohedral Hemihedry, *Liebisch.* No. 19. Rhombohedral Group, *Dana.*

This is by far the most important group in the hexagonal system, and includes the crystals of such minerals as calcite, corundum, hematite and chabazite.

Symmetry of the Class.

Fig. 139 shows the three planes of symmetry at sixty degrees with the three axes diagonal to these and one vertical axis. The axes of symmetry are taken as the crystal axes.

THE GENERAL FORM OR SCALENOHEDRON.

Weiss, $na:\frac{n}{n-1}a:a:mc$; Dana, $m-n$: Miller, $\{hk\bar{l}i\}$.

Composed of twelve faces, Fig. 140, each cutting all the axes. In the ideal form the faces are scalene triangles. The adjacent polar edges are necessarily unequal.

FIG. 139.

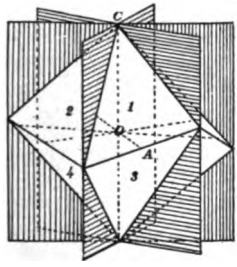
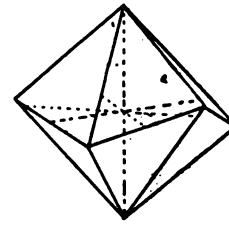


FIG. 140.



To satisfy the symmetry any face, 1, Fig. 139, must be accompanied by a face 2, because of a plane of symmetry, and by a face 3, because OA is an axis of symmetry, and these require others and so on to twelve faces.

The Limit Forms.

Four of the limit forms have been described, namely:

1. BASAL PINACOID, Fig. 119.
3. HEXAGONAL PRISM OF SECOND ORDER, Fig. 121.
4. DIHEXAGONAL PRISM, Fig. 122.
6. HEXAGONAL PYRAMID OF SECOND ORDER, Fig. 124.

The new forms are:

2. TRIGONAL PRISM OF FIRST ORDER.—$a:\infty a:a:\infty c$; I; $\{10\bar{1}0\}$.

Composed of three vertical faces, Fig. 141, each of which is parallel to one basal axis and intersects the others at equal distances from the center, Fig. 141.

FIG. 141.

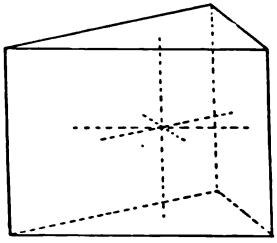
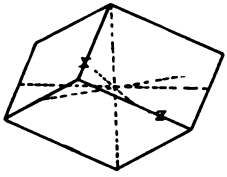


FIG. 142.



RHOMBOHEDRON OF THE FIRST ORDER.—$a : \infty a : a : mc$; m ; $\{hohi\}$.

Composed of six faces, Fig. 142, each cutting two basal axes at equal distances, parallel to the third and cutting the vertical. In the ideal forms the faces are rhombs.

The values of mc may be calculated by the following equations, Fig. 142:

$$\sin a = \cos \tfrac{1}{2}X \times 1.155 ; \tan a \times .866 = mc.$$

Combinations in the Scalenohedral Class.

Calcite.—Axes $a : c = 1 : 0.854$.

Figs. 143 to 150 represent the more common of the extremely numerous combinations shown by crystals of calcite. Rhombohedrons and scalenohedrons predominate. The rhombohedrons

FIG. 143.

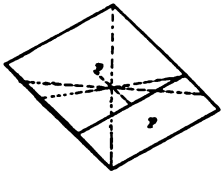


FIG. 144.

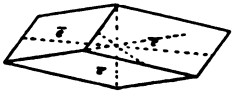


FIG. 145.

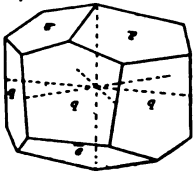


FIG. 146.

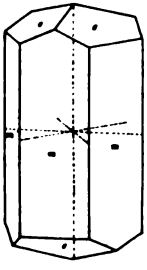


FIG. 147.

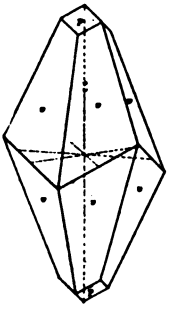
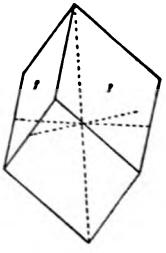


FIG. 148.



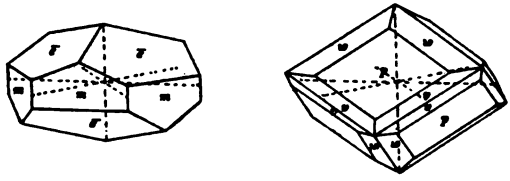
shown are p the unit, Fig. 143, e the negative form of $a : \infty a : a : \frac{1}{2}c$, Fig. 144; f the negative form of $a : \infty a : a : 2c$, Fig. 148; and q the positive form of $a : \infty a : a : 16c$, Fig. 145.

Two scalenohedrons only are shown, $v = \frac{3}{2}a : 3a : a : 3c$, Fig. 147, and $w = \frac{4}{3}a : 4a : a : \frac{4}{5}c$, Fig. 150.

The rhombohedron e occurs more frequently than the unit and is shown in combination with the rhombohedron q in Fig. 145 and with the prism m in 149.

The unit rhombohedron is shown in combination with the scalenohedron v in Fig. 147, and with the two scalenohedrons v and w in Fig. 150.

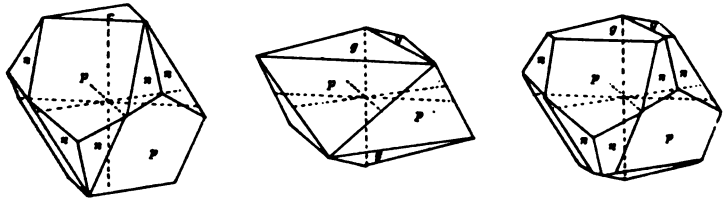
FIGS. 149. FIG. 150.



Hematite.—Axes $a : c = 1 : 1.365$.

Fig. 151 shows the unit rhombohedron p with the basal pinacoid c and the second order pyramid $n = (2a : 2a : a : \frac{4}{3}c)$. Fig. 153 shows the same except that the basal pinacoid is replaced by the rhombohedron $g = (a : \infty a : a : \frac{1}{4}c)$, and Fig. 152 shows the two rhombohedrons p and g.

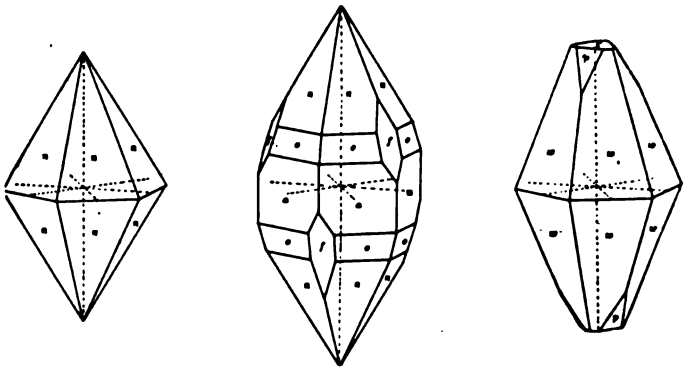
FIG. 151. FIG. 152. FIG. 153.



Corundum.—Axes $a : c = 1 : 1.363$.

The unit forms of hematite and corundum are practically identical, but the combinations and habits are very different. Fig. 154 shows a second order pyramid $n = (2a : 2a ; a : \frac{4}{3}c)$. Fig. 155 shows this and two other second order forms $o = (2a : 2a : a : \frac{8}{3}c)$ and $a = (2a : 2a : a : \infty c)$ and a rhombohedron $f = (a : \infty a : a : 2c)$. Fig. 156 shows a second order pyramid $w = (2a : 2a : a : 2c)$ with the unit rhombohedron p and the basal pinacoid c.

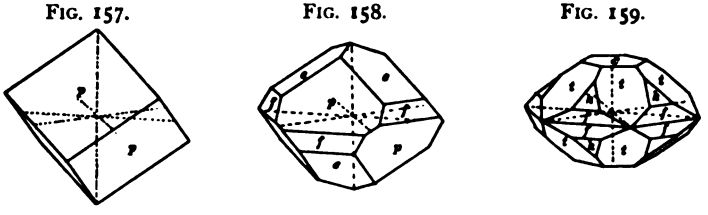
FIG. 154. FIG. 155 FIG. 156.



Chabazite.—Axes $a : c = 1 : 1.086$.

Fig. 157 shows the unit rhombohedron p and Fig. 158 shows this combined with the more acute and more obtuse rhombohedrons $e = (a : \infty a : a : \frac{1}{2}c)$ and $f = (a : \infty a : a : 2c)$. Fig. 159 shows a twin of the variety phacolite.

FIG. 157. FIG. 158. FIG. 159.



HEMIMORPHIC CLASS 20.

No. 14. Second Hemimorphic Tetartohedry, *Liebisch.* No. 20. Rhombohedral Hemimorphic Group, *Dana.*

The common mineral, tourmaline, and the ruby silvers, proustite and pyrargyrite, occur in forms showing different group-

FIG. 160. FIG. 161.

ings of faces at opposite ends of the vertical axis. That is the forms are without horizontal planes or axes of symmetry, Fig. 160.

THE GENERAL FORM OR HEMIMORPHIC DITRIGONAL PYRAMID.

Weiss, $na : \frac{n}{n-1} a : a : mc$; Dana, $m - n$; Miller, $\{hk\bar{l}i\}$.

Composed of six faces, Fig. 161, each cutting all basal axes at simply related distances and all cutting the vertical axis on the same side of the center.

As seen in Fig. 160 if one such face occurs five others must to satisfy the symmetry.

The Limit Forms.

Only two of the forms have been described.

2. TRIGONAL PRISM FIRST ORDER, Fig. 141.

3. HEXAGONAL PRISM SECOND ORDER, Fig. 121.

The geometrically new forms are :

1. The BASAL PLANE, $\infty a : \infty a : \infty a : c : 0$; $\{0001\}$.

Composed of one face parallel to the basal axes.

4. DITRIGONAL PRISM. $na : \frac{n}{n-1} a : a : \infty c$; $i - n$; $\{hk\bar{l}0\}$.

Composed of six faces, Fig. 162, each parallel to the vertical axis and cutting all three basal axes at unequal distances which are simple multiples of each other.

FIG. 162.

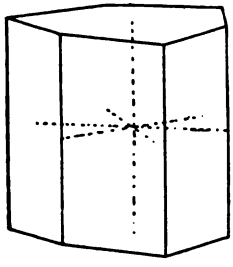


FIG. 163.

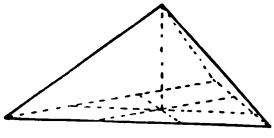
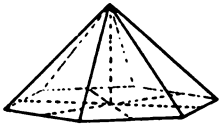


FIG. 164.



5. HEMIMORPHIC TRIGONAL PYRAMID OF FIRST ORDER.

$$a : \infty a : a : mc ;\ m ;\ \{h0\bar{h}i\}.$$

Composed of three faces, Fig. 163, each parallel to one basal axis cutting the other two basal axes at equal distances, and cutting the vertical axis at some distance *not* simply proportionate to the intercepts on the basal axes.

6. HEMIMORPHIC HEXAGONAL PYRAMID OF SECOND ORDER.

$$2a : 2a : a : mc ;\ m - 2 ;\ \{hh2\bar{h}i\}.$$

Composed of six faces, Fig. 164, each cutting one basal axis at a certain distance, the other basal axes at *twice* that distance, and

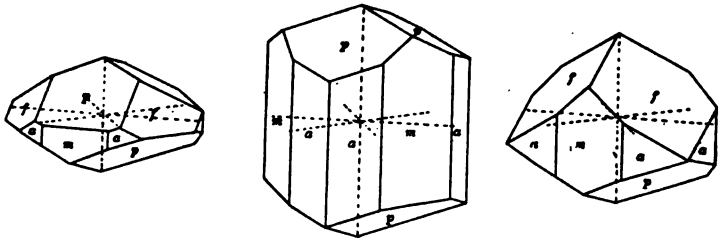
the vertical axis at some distance *not* simply proportionate to the others.

Combinations in the Hemimorphic Class.

Tourmaline.—Axes $a : c = 1 : 0.447$.

Fig. 165 shows the first order trigonal prism m, the second order hexagonal prism a; at the upper end the trigonal pyramids of first order $p = (a : \infty a : a : c)$ and $f = (a : \infty a : a : 2c)$, but at the lower end the trigonal pyramid p only. Fig. 166 shows m, p and a, but does not so evidently reveal the hemimorphic symmetry. Fig. 167 again shows m and a central, with at one end p and at the other f.

FIG. 165. FIG. 166. FIG. 167.



TRAPEZOHEDRAL CLASS. 18.

No. 15. Trapezohedral Tetartohedry, *Liebisch.* No. 22. Trapezohedral Group, *Dana.*

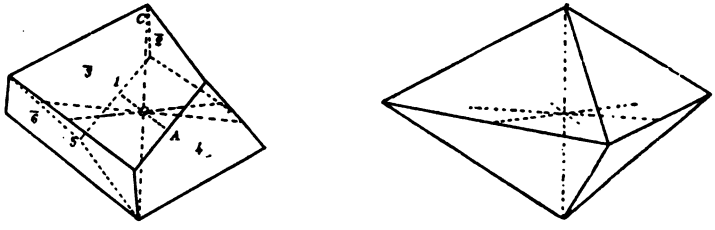
Crystals of the common mineral quartz are without planes of symmetry but are symmetrical to the four axes shown in Fig. 168.

THE GENERAL FORM OR TRIGONAL TRAPEZOHEDRON.

Weiss, $na : \frac{n}{n-1} a : a : mc$; Dana, $m-n$; Miller, $\{ hk\bar{l}i \}$.

Composed of six faces, Fig. 168, each cutting all the axes. In ideal forms these are trapeziums.

FIG. 168. FIG. 169.



Since OC, Fig. 168, is an axis of trigonal symmetry, a face 1 of the general form must be accompanied by faces 2 and 3, and because the other axes, as OA, are axes of binary symmetry, each of these must be accompanied by one of the faces 4, 5 and 6.

The Limit Forms.

Five of the six forms have been described namely:

1. BASAL PINACOID, Fig. 119.
2. HEXAGONAL PRISM OF FIRST ORDER, Fig. 120.
3. HEXAGONAL PRISM OF SECOND ORDER, Fig. 121.
4. DITRIGONAL PRISM, Fig. 162.
5. RHOMBOHEDRON OF FIRST ORDER, Fig. 142.

The geometrical new form is

6. TRIGONAL PYRAMID OF SECOND ORDER. — $2a : 2a : a : mc$; $m-2$; $\{ hh\bar{2}hi \}$.

Composed of six faces, Fig. 169, each cutting two basal axes at an equal distance, the third at half that distance and the vertical somewhere. The faces in the ideal form are isosceles triangles, and a horizontal section is an equilateral triangle.

Combinations in the Trapezohedral Class.

Quartz.—Axes $a : c = 1 : 1.099$.

Fig. 170 shows the positive p and negative $\bar{p}$ unit rhombohedrons, combined in equal proportions. Figs. 172, 173 and 174

FIG. 170.

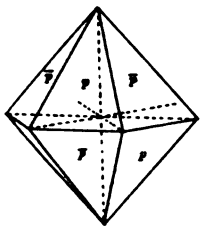


FIG. 171.

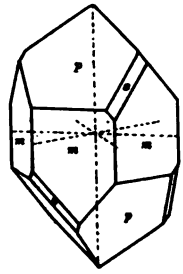


FIG. 172.

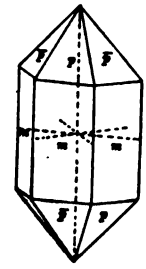


FIG. 173.

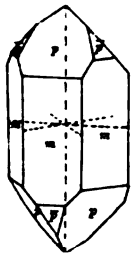


FIG. 174.

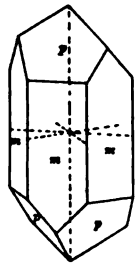


FIG. 175.

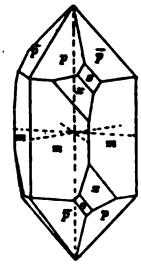
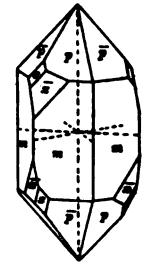


FIG. 176.



show one or both of these combined with the hexagonal prism of first order m.

In Fig. 171 a second order pyramid $s = (2a : 2a : a : 2c)$, necessarily trigonal, occurs with the forms previously mentioned. Fig. 175 and 176 both show the prism m and the two unit rhombohedrons, but in Fig. 175 the second order trigonal pyramid s and the trigonal trapezohedron $x = (\frac{6}{5}a : 6a : a : 6c)$ are both to the right of the positive rhombohedron p, while in Fig. 176 they are to the left. These crystals are called right-handed and left-handed, and represent a structural difference which is also revealed by etching, rotation of the plane of polarization and pyro-electric phenomena.

CLASS OF THIRD ORDER RHOMBOHEDRON. 17.

No. 16. Rhombohedral Tetartohedry, *Liebisch*. No. 21. Trirhombohedral Group, *Dana*.

A number of minerals, ilmenite, dolomite, phenacite, dioptase, willemite, etc., occur in forms which are symmetrical only to a vertical trigonal axis, and to the central point.

THE GENERAL FORM OR RHOMBOHEDRON OF THIRD ORDER.

Weiss, $na : \frac{n}{n-1}a : a : mc$; Dana, $m-n$; Miller, $\{hk\bar{l}i\}$.

Composed of six faces, Fig. 178, each cutting all the axes at unequal distances.

Any face, Fig. 177, must, because of the trigonal axis, be accompanied by two other faces 2 and 3 and each of the three must have a diametrically opposite face, 4, 5 or 6, as in Fig. 177.

FIG 177.

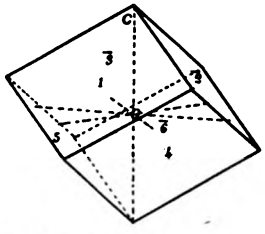
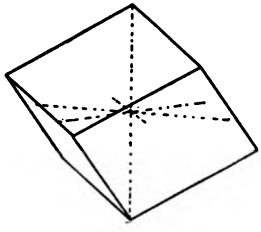


FIG. 178.



The Limit Forms.

Of the six limit forms, five have been described, namely:

1. BASAL PINACOID, Fig. 119.
2. HEXAGONAL PRISM OF FIRST ORDER, Fig. 120.
3. HEXAGONAL PRISM OF SECOND ORDER, Fig. 121.
4. HEXAGONAL PRISM OF THIRD ORDER, Fig. 130.
5. RHOMBOHEDRON OF FIRST ORDER, Fig. 142.

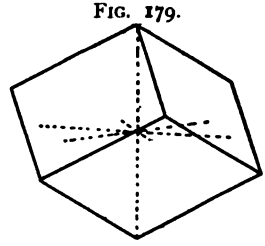
The geometrically new form is:

6. RHOMBOHEDRON OF SECOND ORDER.

$2a : 2a : a : mc$; $m-2$; $\{hh2\bar{h}i\}$.

Composed of six faces, Fig. 179, each cutting two basal axes at twice the distance that it cuts the third, and cutting the vertical somewhere.

FIG. 179.



Combinations in the Class of the Third Order Rhombohedron.

Phenacite.—Axes $a : c = 1 : 0.66107$.

FIG. 180.

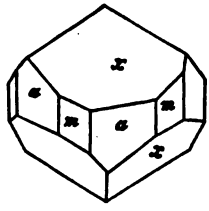


FIG. 181.

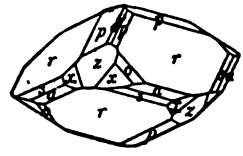


Fig. 180 shows the first order prism m and second order prism a and the third order rhombohedron $x = \frac{3}{2}a : 3a : a : \frac{3}{2}c$.

Fig. 181 shows first order rhombohedrons r, z and d, second order rhombohedrons p and o, third order rhombohedrons x and s and second order prism a.

CHAPTER V.

ORTHORHOMBIC SYSTEM.

The orthorhombic* system includes three classes of symmetry, in all of which the crystallographic axes may be chosen at right angles to each other, but are not interchangeable.

Series.

All forms which ever occur upon crystals of the same substance belong to one series. That is, their faces occur at such angles that if the intercepts of any one face are reduced until one term is unity, then the axial intercepts of *any other* face, taken in the same order and reduced until the same term is unity, will be simple or infinite multiples term for term of those of the first face.

If one of the faces is taken as the unit and its intercepts expressed by $a:b:c$ all other faces may be simply expressed in terms of this face. For instance in the crystals of topaz, Figs. 197 to 199, the calculated intercepts for certain faces and their symbols, when p is taken as the unit face, are as follows:

Face.	Calculated Intercepts.	Symbol in Terms of p.
p	0.528 : 1 : 0.477	$a:b:c$
i	0.528 : 1 : 0.318	$a:b:\frac{2}{3}c$
q	0.528 : 1 : 0.954	$a:b:2c$
m	0.528 : 1 : ∞	$a:b:\infty c$
l	1.156 : 1 : ∞	$2a:b:\infty c$
f	∞ : 1 : 0.954	$\infty a:b:2c$
h	1 : ∞ : 0.318	$a:\infty b:\frac{2}{3}c$

The Choice of the Unit Plane.

The directions of the axes having been determined, the unit plane chosen will if possible be a face of frequent occurrence which intersects all the axes.† The orientation is then optional. One axis, Fig. 182, will be made the vertical, or c, axis, the other two

* Also called Prismatic, Rhombic, Ein-und-einaxige, Anisometric and Trimetric.

† On account of similarity of crystals to some species of related composition, another choice may be made or the values a, b and c may result from two different faces or from cleavages, because of greater brilliancy and more accurate measurements.

will be horizontal, and the horizontal axis with the longer *unit* intercept will be placed to run from left to right, and called the *macro* or $\dot{b}$ axis; the other axis will run from front to back and will be called the *brachy* or $\breve{a}$ axis.

PYRAMIDAL CLASS 8.

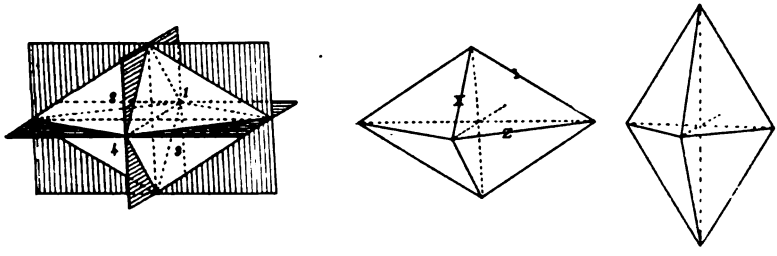
No. 25. Holohedry, *Liebisch*. No. 25. Normal Group, *Dana*.

Almost all orthorhombic minerals crystallize in forms symmetrical to three planes at right angles to each other, as in Fig. 182, the intersections of these being axes of binary symmetry and chosen as the crystallographic axes.

General Form or Pyramid.

Composed of eight faces, Figs. 183 and 184, each of which cuts the three axes in the same relative distances; these intercepts are never simple multiples of each other, but in crystals of the same substance are necessarily simple multiples of the corresponding intercepts of the selected unit pyramid. In the ideal forms the faces are equal scalene triangles.

FIG. 182. FIG. 183. FIG. 184.



The values of $n\breve{a}$ and mc may be determined from any two of the angles X, Y, Z, Fig. 184, by equations like the following:

$$\cos a = \frac{\cos \frac{1}{2}X}{\sin \frac{1}{2}Z}, \qquad na = \cot a.$$

$$\cos \beta = \frac{\cos \frac{1}{2}Z}{\sin \frac{1}{2}X}, \qquad mc = \tan \beta \times n\breve{a}.$$

Evidently a rhombic pyramid may be composed either of faces with the unit intercepts, or the faces may be at other angles,

with any one or two of the intercepts simple multiples of the unit intercepts. Three types are distinguished, the symbols being :*

	Weiss.	Dana.	Miller.
Unit series Pyramids,	$\breve{a} : \dot{b} : mc$	m	$\{ hhl \}$
Macro Pyramids,	$\breve{a} : n\dot{b} : mc$	$m - \ddot{n}$	$\{ hkl \}$
Brachy Pyramids,	$n\breve{a} : \dot{b} : mc$	$m - \breve{n}$	$\{ khl \}$

Limit Forms.

The general form for special positions of the faces may become one of six limit forms, as follows :

Each face parallel to two axes.	Weiss.	Dana.	Miller.
1. Basal Pinacoid.	$\infty\breve{a} : \infty\dot{b} : c$	0	$\{ 001 \}$
2. Macro Pinacoid.	$\breve{a} : \infty\bar{b} : \infty c$	$i - \bar{i}$	$\{ 100 \}$
3. Brachy Pinacoid.	$\infty\breve{a} : \dot{b} : \infty c$	$i - \breve{i}$	$\{ 010 \}$
Each face parallel to one axis.			
4. Brachy Dome.	$\infty\breve{a} : \dot{b} : mc$	$m - \breve{i}$	$\{ 0kl \}$
5. Macro Dome.	$\breve{a} : \infty\dot{b} : mc$	$m - \bar{i}$	$\{ h0l \}$
6. Prism.	$\breve{a} : n\bar{b} : \infty c$	$i - n$	$\{ hk0 \}$
	$n\breve{a} : \bar{b} : \infty c$	$i - \breve{n}$	$\{ kh0 \}$

The Limit Forms in Detail.

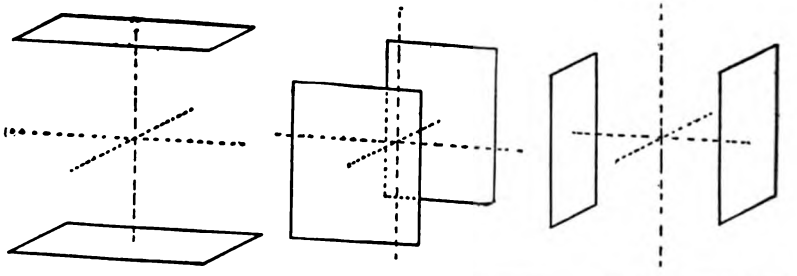
1. Basal Pinacoid.— $\infty\breve{a} : \infty\dot{b} : c$; 0 ; $\{ 001 \}$.

Composed of two faces, Fig. 185, each parallel to the basal axes.

2. Macro Pinacoid.—$\breve{a} : \infty\bar{b} : \infty c$; $i - \bar{i}$; $\{ 100 \}$.

Composed of two faces, Fig. 186, each parallel to the macro and vertical axes.

Fig. 185. Fig. 186. Fig. 187.



* It is customary to assume n as varying only from 1 to ∞, never less than 1 ; that is, the very possible value, $\frac{1}{2}a : b : 2c$, is represented by $a : 2b : 4c$, n being made greater than 1 by transferring it from a to b with an appropriate value.

3. BRACHY PINACOID.— $\infty \breve{a} : \bar{b} : \infty c$; $i - \breve{i}$; $\{ 010 \}$.

Composed of two faces, Fig. 187, each parallel to the brachy and vertical axes.

4. BRACHY DOME.— $\infty \breve{a} : \bar{b} : mc$; $m - \breve{i}$; $\{ 0kl \}$.

Composed of four faces, Fig. 188, each parallel to the brachy axis but cutting the macro axis and vertical axis in distances *not* simply proportionate.

The value of *mc* may be determined by the equation, Fig. 188,

$$\tan \tfrac{1}{2} B = mc.$$

5. MACRO DOME.—$\breve{a} : \infty \bar{b} : mc$; $m - \bar{i}$; $\{ h0l \}$.

Composed of four faces, Fig. 189, each parallel to the macro axis but cutting the brachy axis and the vertical axis in distances *not* simply proportionate.

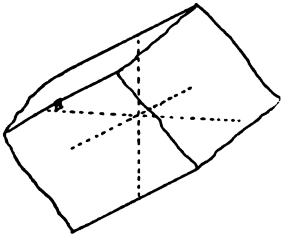


FIG. 188.

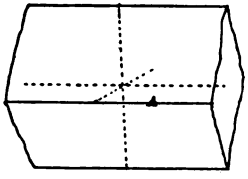


FIG. 189.

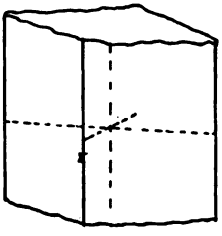


FIG. 190.

The value of *mc* may be determined by the equation, Fig. 189,

$$\tan \tfrac{1}{2} A = \frac{mc}{a}.$$

6. PRISM.

Composed of four faces, Fig. 190, each parallel to the vertical axis and cutting the basal axes in distances *not* simply proportionate.

The intercepts on the basal axes may be in the unit ratio or one of the intercepts may be *relatively* lengthened.

The types receive names and symbols as follows :

Unit Prism,	$\breve{a} : \bar{b} : \infty c$	I	$\{ 110 \}$
Macro Prism,	$\breve{a} : n\bar{b} : \infty c$	$i - n$	$\{ hk0 \}$
Brachy Prism,	$n\breve{a} : \bar{b} : \infty c$	$- \breve{n}$	$\{ kh0 \}$.

The value of *na* can be determined by the equation, Fig. 190.

$$\cot \tfrac{1}{2} X = na.$$

Combinations in the Pyramidal Class.

Barite.—Axes $\breve{a} : \bar{b} : c = 0.815 : 1 : 1.313$.

The prevailing faces are the unit prism m, the basal pinacoid c, the macro dome $n = (\breve{a} : \infty b : \frac{1}{2} c)$, and the brachy dome $d = (\infty \breve{a} : \bar{b} : c)$.

FIG. 191. FIG. 192. FIG. 193.

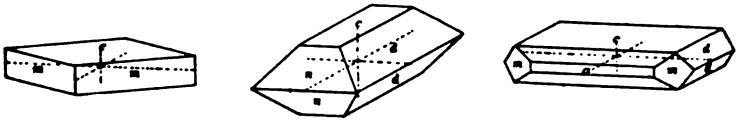
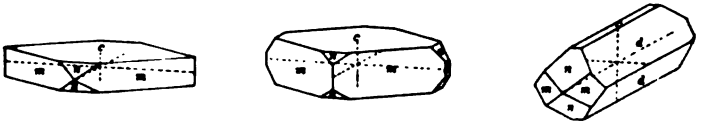


FIG. 194. FIG. 195. FIG. 196.



All of these are shown in Fig. 196. Fig. 195 contains also the brachy pinacoid b and Fig. 193 the macro pinacoid a. Figs. 191, 192 and 194 are simpler combinations of the same forms.

Topaz.—Axes $\breve{a} : \bar{b} : c = 0.528 : 1 : 0.477$.

Fig. 197 shows the unit pyramid p, unit prism m, brachy prism $l = (2\breve{a} : b : \infty c)$ and the brachy dome $f = (\infty \breve{a} : \bar{b} : 2c)$. Fig. 198 shows the same forms with the basal pinacoid c and

FIG. 197. FIG. 198. FIG. 199.

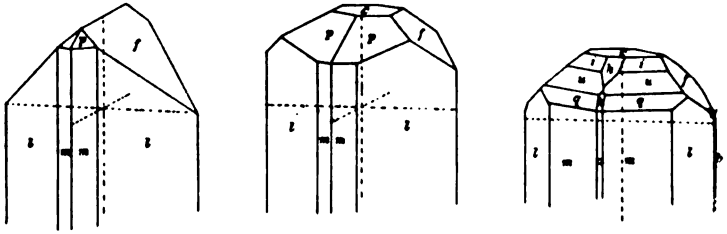


Fig. 199 shows all of 198 and also two other pyramids $i = \breve{a} : \bar{b} : \frac{2}{3} c$; $q = \breve{a} : \bar{b} : 2c$; and two macro-domes $h = \breve{a} : \infty b : \frac{2}{3} c$ and $k = \breve{a} : \infty \bar{b} : 2c$.

HEMIMORPHIC CLASS. 7.

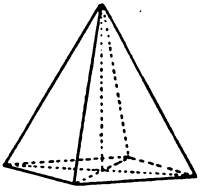
No. 27. Hemimorphy, *Liebisch.* No. 26. Hemimorphic Group, *Dana.*

The mineral calamine, occurs in crystals which are symmetrical to only two planes and their intersection. That is the faces are different at opposite ends of the axis of symmetry.

THE GENERAL FORM OR HEMIMORPHIC PYRAMID.

Composed of four faces, Fig. 235, each cutting all three axes. Just as in the general form of the preceding class the symbol may be any one of:

FIG. 200.



WEISS.	DANA.		MILLER.
$a : \breve{b} : mc$	m		$\{ hhl \}$
$a : n\bar{b} : mc$	$m - \bar{n}$		$\{ hkl \}$
$na : \bar{b} : mc$	$m - \breve{n}$	m	$\{ khl \}$

Limit Forms.

Three of the limit forms are geometrically like the forms of the preceding class namely:

2. MACRO PINACOID. Fig. 186.
3. BRACHY PINACOID. Fig. 187.
6. RHOMBIC PRISM. Fig. 190.

The geometrically new forms are:

1. BASAL PLANE.— $\infty a : \infty b : c$; 0; $\{ 001 \}$.

Composed of one face parallel to the basal axes.

4. HEMIMORPHIC BRACHY DOME.— $\infty a : \breve{b} : mc$; $m - \breve{\imath}$; $\{ 0kl \}$.

Composed of two faces, Fig. 201, each parallel to the brachy axis.

FIG. 201.

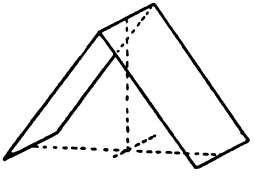
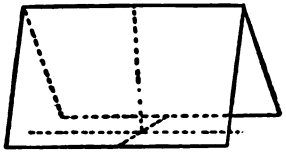


FIG. 202.



5. HEMIMORPHIC MACRO DOME.—$\breve{a} : \infty\bar{b} : mc$; $m - \breve{\imath}$; $\{ hol \}$.

Composed of two faces, Fig. 202, each parallel to the macro axis.

Combinations in the Hemimorphic Class.

Fig. 203 shows a crystal of calamine with the unit prism m and the macro and brachy pinacoids a and b. One end shows only the hemimorphic pyramid $v = (2\breve{a} : \breve{b} : 2c)$, the other shows the basal plane, c, the two brachy domes $d = (\infty\breve{a} : \bar{b} : c)$ and $i = (\infty\breve{a} : \bar{b} : 3c)$ and the macro dome $t = \breve{a} : \infty\bar{b} : 3c$.

The other class in this system has a representative in epsomite, the characteristic form being the sphenoid *p*, Fig. 204.

FIG. 203.

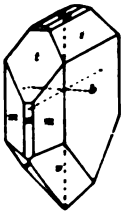
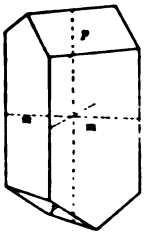


FIG. 204.

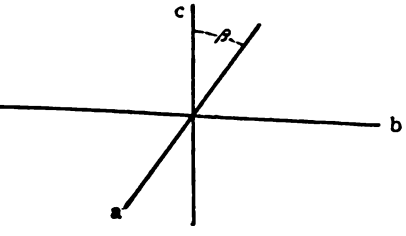


CHAPTER VI.

MONOCLINIC SYSTEM.*

The monoclinic system includes three classes of symmetry, in ll of which the crystallographic axes may be chosen so that two re oblique to each other and the third normal to the other two. 'he axes, Fig. 205, are not interchangeable.

FIG. 205.



Conventionally the normal or "ortho" axis $\bar{b}$ is placed from right to left, either of the other axes is made the vertical, c, and the third "the clino," $\grave{a}$, dips downward from back to front. The acute angle between the vertical and clino axis is called β.

Series.

All that has been said as to series under the orthorhombic system on p. 48 may be repeated here. The axes are understood to be fixed with one definite value for β for all forms of the series.

PRISMATIC CLASS. 5.

No. 28. Holohedry, *Liebisch.* No. 28. Normal Group, *Dana.*

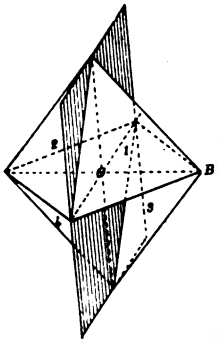
All the common monoclinic minerals occur in crystals symmetrical to one plane and to one axis normal to the plane, Fig. 206.

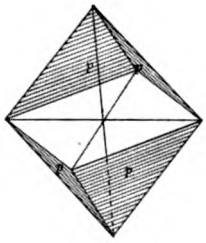
GENERAL FORM OR HEMI PYRAMID.

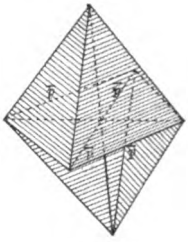
Composed of four faces each intersecting all the axes in distances not simple multiples of each other. For any symbol two independent forms result, each of four faces. The four in Fig. 207 constitute the so-called *positive* hemi pyramid, those in Fig. 208 the *negative*.

* Also called Hemiprismatic, Zwei-und-eingliedridge, Monoclinohedral, Clinorhombic, Monosymmetric.

FIG. 206. FIG. 207. FIG. 208.







Just as in the orthorhombic system the faces of a hemi pyramid may have the unit intercepts or any one or two of the intercepts may be simple multiples of those of the unit face. To distinguish the possible varieties the following names and symbols are needed:

	WEISS.	DANA.	MILLER.
Positive Unit Series Pyramid,	$+\dot{a}:\bar{b}:mc$	$+m$	$\{\bar{h}hl\}$
Negative Unit Series Pyramid,	$-\dot{a}:\bar{b}:mc$	$-m$	$\{hhl\}$
Positive Ortho Pyramid,	$+\dot{a}:n\bar{b}:mc$	$+m-\bar{n}$	$\{\bar{h}kl\}$
Negative Ortho Pyramid,	$-\dot{a}:n\bar{b}:mc$	$-m-\bar{n}$	$\{hkl\}$
Positive Clino Pyramid,	$+n\dot{a}:\bar{b}:mc$	$+m-\grave{n}$	$\{\bar{k}hl\}$
Negative Clino Pyramid,	$-n\dot{a}:\bar{b}:mc$	$-m-\grave{n}$	$\{khl\}$

Limit Forms.

The general form will, for certain positions of the faces, pass into limit forms as follows:

Each face parallel to two axes.	WEISS.	DANA.	NAUMAN.
1. BASAL PINACOID.	$\infty\dot{a}:\infty\bar{b}:c$	0	{001}
2. ORTHO PINACOID.	$\dot{a}:\infty\bar{b}:\infty c$	$i-\bar{1}$	{100}
3. CLINO PINACOID.	$\infty\dot{a}:\bar{b}:\infty c$	$i-\dot{1}$	{010}
Each face parallel to one axis.			
4. CLINO DOME.	$\infty\dot{a}:\bar{b}:mc$	$m-\dot{1}$	{0kl}
5. ORTHO DOME.	$\dot{a}:\infty\bar{b}:mc$	$m-\bar{1}$	{h0l}
6. PRISM.	$\dot{a}:n\bar{b}:\infty c$	$i-\bar{n}$	{hk0}
	$n\dot{a}:\bar{b}:\infty c$	$i-\grave{n}$	{kh0}

Limit Forms in Detail.

1. BASAL PINACOID.— $\infty \dot{a} : \infty \bar{b} : c$; 0; $\{001\}$.

Composed of two faces, Fig. 209, each parallel to both basal axes.

2. ORTHO PINACOID.—$\dot{a} : \infty \bar{b} : \infty c$; $i-\bar{i}$; $\{100\}$.

Composed of two faces, Fig. 210, each parallel to the ortho and vertical axes.

FIG. 209.

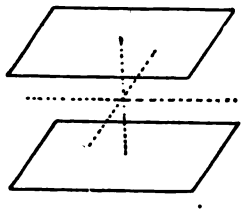
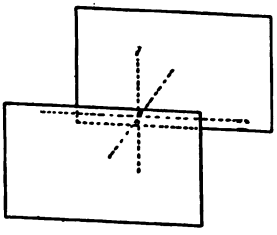


FIG. 210.



3. CLINO PINACOID.— $\infty \dot{a} : \bar{b} : \infty \dot{c}$; $i-\dot{i}$; $\{010\}$.

Composed of two faces, Fig. 211, each parallel to the clino and vertical axes.

4. CLINO DOMES.— $\infty \dot{a} : \bar{b} : mc$; $m-\dot{i}$; $\{0kl\}$.

Composed of four faces, Fig. 212, each parallel to the c no axis and cutting the vertical and ortho axes in distances *not* simply proportionate.

FIG. 211.

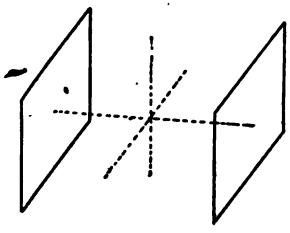
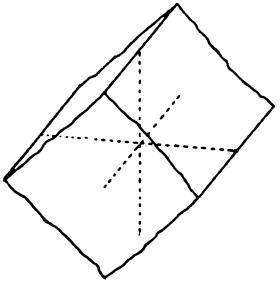


FIG. 212.



5. HEMI ORTHO DOME.

Composed of two opposite faces, each parallel to the ortho axis and cutting the clino and vertical axes in distances not simply proportionate.

If the faces lie in the acute angle β, the form is called positive. Fig. 213, if they lie in the obtuse angle, the form is called negative.

Positive $+\grave{a}:\ \infty b:\ mc;\quad +m-\bar{\imath};\quad \{h o \bar{l}\}$.
Negative $-\grave{a}:\ \infty \bar{b}:\ mc;\quad -m-\bar{\imath};\quad \{h o l\}$.

FIG. 213.

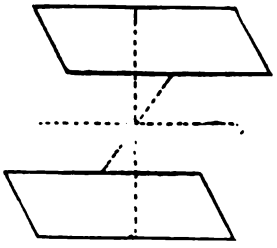
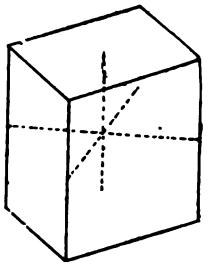


FIG. 214



6. PRISM.

Composed of four faces, Fig. 214, each parallel to the vertical axis, and cutting the basal axes in distances not simply proportionate.

As in the pyramids, a prism compared with the chosen unit plane may be:

Unit Prism	$\grave{a}:\bar{b}\ \infty c$	I	$\{110\}$
Ortho Prism	$\grave{a}:n\bar{b}:\ \infty c$	$i-\bar{n}$	$\{hk0\}$
Clino Prism	$n\grave{a}:\bar{b}:\infty c$	$i-\grave{n}$	$\{kh0\}$

The ratio between $\grave{a}$ and $\bar{b}$ cannot be determined from the prismatic angle alone: if, however, the angle B of the unit prism is known, the value of n for any other prism may be determined by measuring its angle B' and using the equation: $n=\dfrac{\tan\frac{1}{2}B'}{\tan\frac{1}{2}\beta}$.

If the angle A between the basal pinacoid and unit prism is known and the prism angle B, the ratio between the axis and also the angle β may be determined by the equations:

$$\cos\delta=\frac{\cos\frac{1}{2}B}{\sin A};\quad \frac{\grave{a}}{\bar{b}}=\cot\delta;\quad \cos\beta=\frac{\cos A}{\sin\frac{1}{2}\beta}.$$

In clino and ortho prisms the values of n may be determined when the angle β is known:

$$\bar{n}=a\tan\tfrac{1}{2}B\sin\beta;\quad \grave{n}=\frac{\cot\frac{1}{2}B}{a\sin\beta}$$

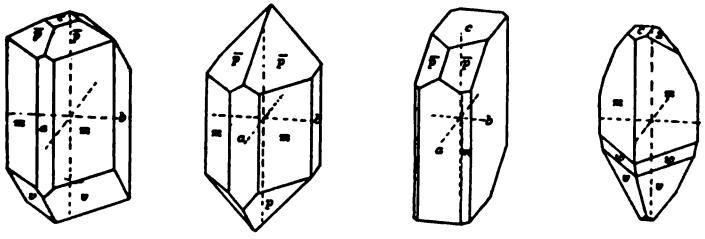
Combinations Prismatic Class.

Pyroxene.—Axes $\grave{a}:\bar{b}:c=1.092:1:0.589$; $\beta=74^\circ\ 10'\ 9''$.

Fig. 215 shows the three pinacoids, a, b and c, the unit prism m,

the negative unit hemi-pyramid $\bar{p}$ and the positive hemi-pyramid $v = (\dot{a} : \bar{b} : 2c)$. Fig. 217 is the same without v and Fig. 216 omits also the basal pinacoid c. Fig. 218 shows the unit prism m, the basal

FIG. 215. FIG. 216. FIG. 217. FIG.



pinacoid c, two positive hemi-pyramids v and $w = (\dot{a} : \bar{b} : 3c)$ and a clino dome $z = (\infty \dot{a} : \bar{b} : 2c)$.

AMPHIBOLE.—Axes $\dot{a} : \bar{b} : c = 0.551 ; 1 : 0.293 ; \beta = 73° 58' 4''$.

FIG. 219. FIG. 220. FIG. 221.

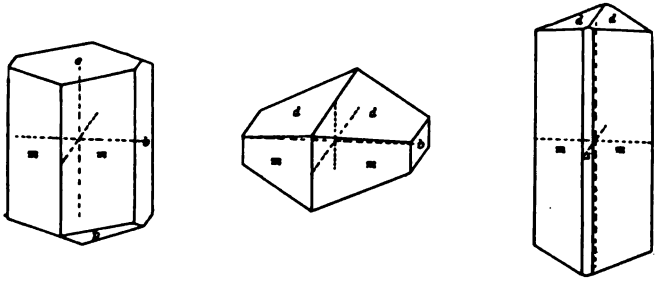
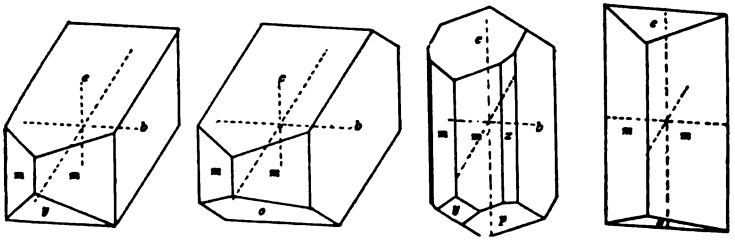


Fig. 219 shows the unit prism m, the basal and clino pinacoids, c and b and the positive unit hemi pyramid p. Fig. 220 shows the unit prism, clino pinacoid and unit clino dome $d = (\infty \dot{a} : \bar{b} : c)$. Fig. 221 shows the same except that the clino pinacoid b is replaced by the ortho pinacoid a.

FIG. 222. FIG. 223 FIG. 224. FIG. 225.



ORTHOCLASE.—Axes $\dot{a} : \dot{b} : c = 0.658;\ 1 : 0.555;\ \beta = 63° 56' 46''$.

Fig. 222 shows the unit prism m, clino and basal pinacoids b and c, and positive hemi orthodome $y = (\dot{a} : \infty \bar{b} : 2c)$. In Fig. 223 y is replaced by $o = (\dot{a} : \infty \bar{b} : c)$, and in Fig. 225 the clino pinacoid is omitted. Fig. 224 includes the forms of 257 and also a clino prism $z = 3\dot{a} : \bar{b} : \infty c$ and the unit pyramid p.

Not one of the common monoclinic minerals is known to crystallize in either of the other two classes possible in the system.

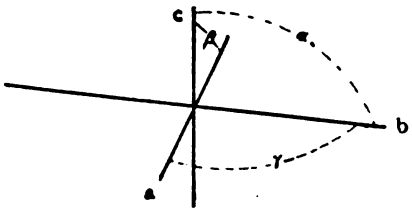
CHAPTER VII.

TRICLINIC SYSTEM.*

The Triclinic System has been divided into two classes in both which the crystallographic axes are three lines oblique to each ıer and not interchangeable.

The three axes, Fig. 226, usually chosen parallel to ɔminent edges of the crystal. One of the three chosen axes placed in a vertical position, d is called the vertical axis, Of the others, the brachy ıs $\breve{a}$ takes the position of the ıo axis in the monoclinic system and the macro axis $\bar{b}$ takes its sition according to its angles with $\breve{a}$ and c.

FIG. 226.



The oblique angles between the axes are conventionally desig-ed by Greek letters as follows:

$$\breve{a} \wedge \bar{b} \text{ by } \gamma; \quad \breve{a} \wedge c \text{ by } \beta; \quad \bar{b} \wedge c \text{ by } \alpha.$$

ries.

As in the preceding systems all the "forms" in which one sub-nce ever crystallizes belong to the same series, that is, if erred to three axes inclined at certain constant values for α, β d γ, the intercepts of any two faces reduced until the same term each is unity, and the corresponding terms divided the one by other; the quotients will be either simple numbers, simple frac-ıs, or infinity.

PINACOIDAL CLASS. 2.

No. 31. Holohedry, *Liebisch*. No. 31. Normal Class, *Dana*.

All known triclinic minerals crystallize in forms symmetrical to center only. Every form must therefore consist of *two* faces.

*Also known as Tetarto prismatic, Ein-und-eingliedrige, Triclinohedral, Clinorhom-al, Anorthic, Doubly oblique and Asymmetric.

General Form or Tetrapyramid.

Composed of two opposite faces, Fig. 227, which may be, as in the orthorhombic, unit, macro or brachy.

	Weiss.	Dana.	Miller.
Unit Series,	$\breve{a} : \bar{b} : mc$	m	$\{ hhl \}$
Macro,	$\breve{a} : n\bar{b} : mc$	$m - \bar{n}$	$\{ hkl \}$
Brachy,	$n\breve{a} : \bar{b} : mc$	$m - \breve{n}$	$\{ khl \}$

According to the position of the faces with reference to the axes, names and symbols may be given. Thus, for four tetrapyramids of the unit series :

Upper Right Tetra-Pyramid,	$\breve{a} : \bar{b} : mc$	m'	$\{ hhl \}$
Upper Left Tetra-Pyramid,	$\breve{a} : \bar{b}' : mc$	$'m$	$\{ h\bar{h}l \}$
Lower Right Tetra-Pyramid,	$\breve{a}' : \bar{b}' : mc$	$m_{,}$	$\{ \bar{h}\bar{h}l \}$
Lower Left Tetra-Pyramid,	$\breve{a}' : \bar{b} : mc$	$_{,}m$	$\{ \bar{h}hl \}$

Fig. 227.

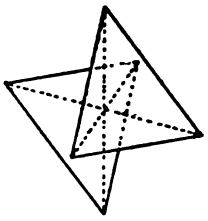
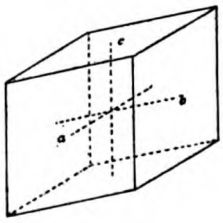


Fig. 228.



Limit Forms.

The general form for certain positions of the faces will pass into limit forms as follows :

Each face is parallel to two axes.	Weiss.	Dana.	Miller.
1. Basal Pinacoid,	$\infty\breve{a} : \infty\bar{b} : c$	0	$\{ 001 \}$
2. Macro Pinacoid,	$\breve{a} : \infty\bar{b} : \infty c$	$i - \bar{1}$	$\{ 100 \}$
3. Brachy Pinacoid,	$\infty\breve{a} : \bar{b} : \infty c$	$i - \breve{1}$	$\{ 010 \}$
Each face is parallel to one axis.			
4. Hemi Brachy Dome,	$\infty\breve{a} : b : mc$	$m - {}_{,}1'$	$\{ okl \}$
5. Hemi Macro Dome,	$\breve{a}' : \infty b : mc$	$m - {}_{,}\bar{1}_{,}$	$\{ hol \}$
6. Hemi Prism,	$\breve{a} : nb : \infty c$	$i - \bar{n}'$	$\{ hko \}$

The Limit Forms in Detai .

1. Basal Pinacoid.— $\infty\breve{a} : \infty\bar{b} : c$; 0 ; $\{ 001 \}$.

Composed of two faces parallel to the basal axes. The faces c in Figs 228 and 233.

2. MACRO PINACOID.—$\breve{a} : \infty\bar{b} : \infty c$; $i - \breve{\imath}$; $\{ 100 \}$.

Composed of two faces parallel to the macro and vertical axes. The faces *a* of Figs. 228, 232, 233 and 234.

3. BRACHY PINACOID.— $\infty \breve{a} : \bar{b} : \infty c$; i–$\breve{\imath}$; $\{ 010 \}$.

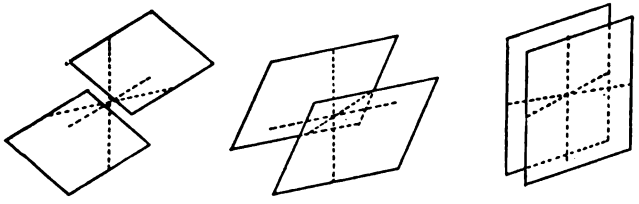
Composed of two faces, each parallel to the brachy and vertical axes. The faces *b* of Figs. 228, 232, and 233.

4. HEMI BRACHY DOMES.

Composed of two faces, Fig. 229, parallel to $\breve{a}$ and intersecting $\bar{b}$ and *c* in distances not simply related. According to the position the form may be:

Right upper,	$\infty \breve{a} : \bar{b} : mc$	$m-, i'$	$\{ 0kl \}$
Left upper,	$\infty \breve{a} : \bar{b}' : mc$	$m-' i,$	$\{ 0\bar{k}l \}$

FIG. 229. FIG. 230. FIG. 231.



5. HEMI MACRO DOME.

Composed of two faces, Fig. 230, each parallel to the macro axis and cutting the brachy axis and the vertical axis in distances *not* simply proportionate.

According to position the form may be:

Upper front,	$\breve{a} : \infty \bar{b} : mc$	$m-' i'$	$\{ hol \}$
Lower front,	$\breve{a}' : \infty \bar{b} : mc$	$m-, i,$	$\{ \bar{h}ol \}$

6. HEMI PRISM.

Composed of two opposite faces, Fig. 231, each parallel to the vertical axis and intersecting the basal axes. The same division is made into macro, brachy and unit as in the orthorhombic. For instance:

Right Brachy,	$n\breve{a} : b : \infty c$	i–$\breve{n}'$	$\{ kho \}$
Left Brachy,	$n\breve{a} : b' : \infty c$	i–$'\breve{n}$	$\{ k\bar{h}o \}$

Combinations in the Triclinic System.

Fig. 232 shows a crystal of chalcanthite with brachy pinacoid *b*, macro pinacoid *a*, right hemi prism *m*, left hemi prism *M* and lower

left tetra pyramid p. Fig. 233 shows a crystal of cyanite with the three pinacoids a, b and c, the right m, and left M hemi unit prisms and a right hemi brachy prism $l=(2\breve{a} : b : \infty c)$.

FIG. 232.

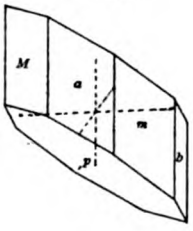


FIG. 233

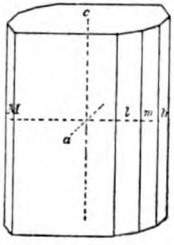


FIG. 234.

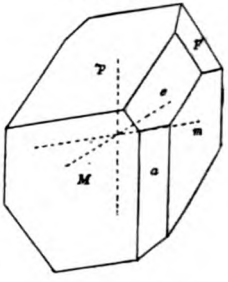


Fig. 234 shows a crystal of axinite with both hemi prisms m and M, macro pinacoid a, upper right and upper left unit pyramids p' and $'p$ and a macro dome $e = \breve{a} : \infty\bar{b} : 2c$.

CHAPTER VIII.

TWINNED CRYSTALS.

ystals frequently occur in which the faces, while evidently
ging to more than one individual, possess a very definite
ion with respect to each other, usually symmetrical to a defi-
plane called a twinning plane.

ch a symmetrical intergrowth of two like crystals is called a
ed crystal. When the two individuals penetrate each other
constitute a penetration twin and when they do not they con-
e a contact twin.

ning Plane.

ie twinning plane, since it is a plane of symmetry for the pair
ystals, cannot be a plane of symmetry for either individually.
usually, however, parallel to a crystal face of simple symbol.

Axis.

ie line normal to the twinning plane is called the *twin axis*
usually the two individuals are in the relative positions corre-
ding to a half revolution about this line of one of two originally
lel individuals. Evidently this twin axis cannot be an axis of
y symmetry, p. 4, because a rotation of 180° about it would
the crystals into an identical instead of a reversed position.
the same reason the twin axis cannot be an axis of tetragonal
exagonal symmetry, though it could be an axis of trigonal
netry. The twin axis will usually, however, be either a crys-
graphic axis or normal to some very prominent face.

ISOMETRIC TWINS.

ning Plane an Octahedron Face.

ie most frequent type is with the twinning plane an octahedral
Fig. 235 shows an octahedron with the twinning plane shaded
the twin axis AA normal thereto ; Fig. 237 shows the corres-
ling contact twin, and Fig. 236 the interpenetrating twin.

g. 238 shows a combination of cube and octahedron, the twin
e shaded and the twin axis AA normal thereto. Fig. 239

shows two such crystals united in reversed positions. Fig. 240 shows two cubes interpenetrating.

Fig. 235.

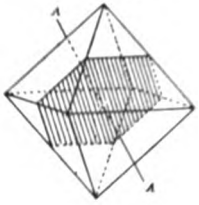


Fig. 236.

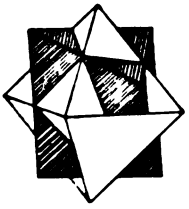


Fig. 237.

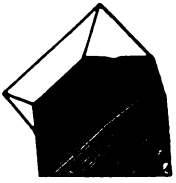


Fig. 238.

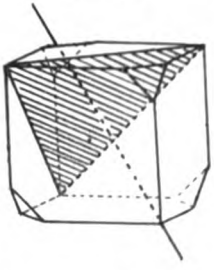


Fig. 239.

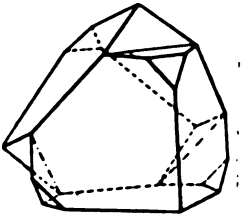
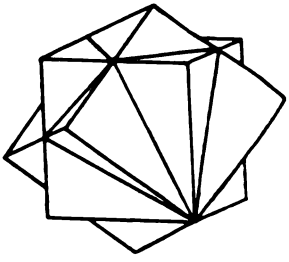


Fig. 240.



Twinning Plane a Cube Face.

A cube face can be a twinning plane in the class of the hex-tetrahedron, p. 18.

Fig. 241 shows the tetrahedron with the twinning plane shaded and the twin axis *OA* normal thereto. Fig. 242 shows the penetration twin, the reversed tetrahedron being shaded.

Fig. 241.

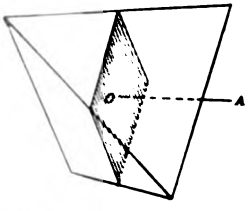
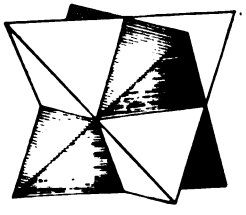


Fig. 242.



Twinning Plane a Dodecahedron Face.

A face of the dodecahedron can be a twinning plane in the class of the diploid. Fig. 243 shows a pyritohedron with twinning plane shaded and twin axis *OA* normal thereto. Fig. 244 shows the penetration twin, the reversed form being shaded.

FIG. 243.

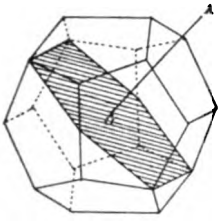
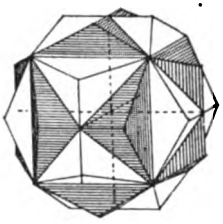


FIG. 244.



TETRAGONAL TWINS.

Twinning Plane a Face of Second Order Pyramid.

This is the most common type. Fig. 245 shows a cassiterite crystal with such a plane shaded. Fig. 246 shows the contact

FIG. 245.

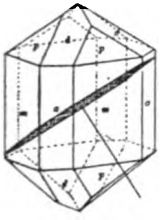


FIG. 246.

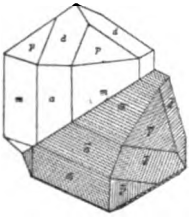
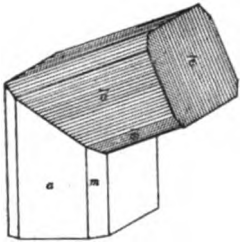


FIG. 247.



twin, the reversed form being shaded. Fig. 247 shows a similar contact twin of rutile. Fig. 248 shows the pyramid of hausmannite with twinning plane shaded. Fig. 249 shows a contact twin

FIG. 248.

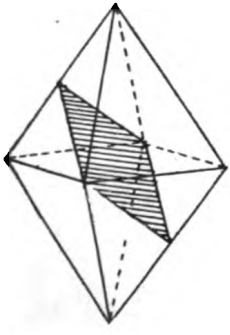


FIG. 249.

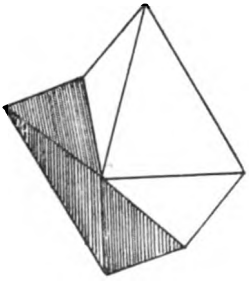
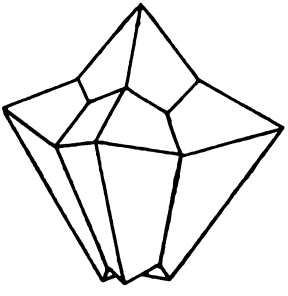


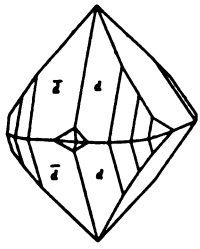
FIG. 250.



and Fig. 250 shows four pyramids which have grown about a fifth in normal position, each of the pyramids with a twinning plane parallel to a different face of the second order pyramid.

Other planes may be twinning planes. Chalcopyrite occurs with twinning plane parallel to a first order pyramid face. In scheelite, Fig. 251, the twinning plane is parallel to a face of the second order prism.

FIG. 251.



HEXAGONAL TWIN.

Twins are rare in the class of highest symmetry of this system. In the scalenohedral class twins occur with the twinning plane parallel to a rhombohedron or base but not to a prism face. In quartz, however, which belongs to the trapezohedral class, p. 44, without planes of symmetry, the twinning plane is frequently a prism face.

Twinning Plane a Face of a Rhombohedron.

Fig. 252, represents a calcite unit rhombohedron with a twin-

FIG. 252.

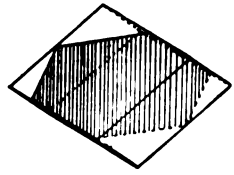
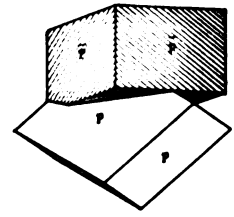


FIG 253.



ning plane parallel to $a : \infty a : a : \frac{1}{2}c$ shaded, Fig. 253 shows the twin with the reversed form shaded.

Twinning Plane the Basal Pinacoid.

In calcite and other minerals of the scalenohedral class, p. 39, the basal pinacoid is sometimes the twinning plane. Fig. 254

FIG. 254.

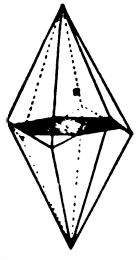


FIG. 255.

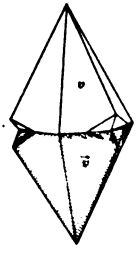


FIG. 256

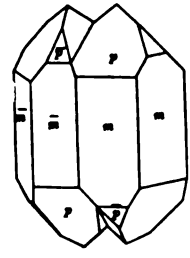
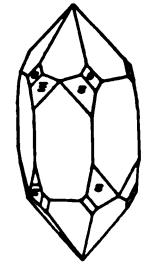


FIG. 257.



shows a calcite scalenohedron with twinning plane shaded, and Fig. 255 shows the corresponding contact twin.

Twinning Plane a Face of First Order Prism.

In quartz, twins of this kind occur like Fig. 256, but more frequently interpenetrating and as then the positive rhombohedron of one coincides with the negative of the other, the twin structure is only recognized by etching.

Twinning Plane a Face of Second Order Prism.

If this occur in quartz the twin is not a true twin if both individuals are positive or both negative for the positions after revolution, are identical and not reversed. If one is positive and the other negative the result is as in Fig. 257 and basal sections will show characteristic optical phenomena.

ORTHORHOMBIC TWINS.

The pinacoids will not be twinning planes but any other face may be.

Twinning Plane a Prism Face.

Fig. 258 shows such a contact twin of aragonite and Fig. 259 shows the pseudohexagonal shape frequent in this mineral as a result of repeated twinning.

FIG. 258.

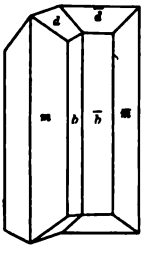
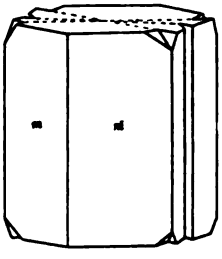


FIG. 259.



Twinning Plane a Dome Face.

Fig. 260 shows a staurolite crystal with a plane parallel to a brachy dome $\infty\breve{a} : \dot{b} : \frac{8}{2}c$ shaded. Fig. 261 shows the interpenetration twin the reversed form shaded.

FIG. 260.

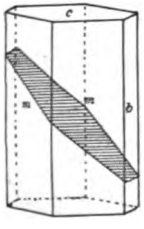


FIG. 261.

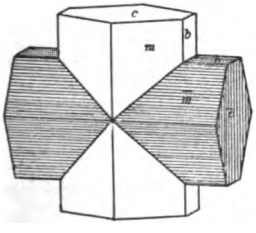


FIG. 262.

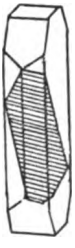
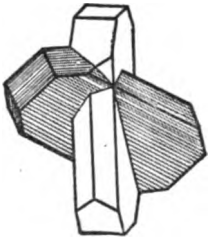


FIG. 263.



Twinning Plane a Pyramid Face.

Fig. 262 shows a staurolite crystal with twin plane $\frac{8}{2}\breve{a} : \bar{b} : \frac{8}{2}c$ shaded. Fig. 263 shows the corresponding interpenetration twin.

MONOCLINIC TWINS.

The plane of symmetry will not be a twin plane, any other may be.

Twinning Plane the Orthopinacoid.

FIG. 264.

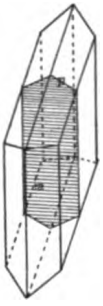
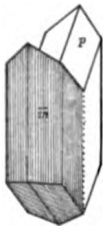


FIG. 265.



This is the most common type. Fig. 264 shows a gypsum crystal with a shaded plane parallel to the orthopinacoid, and Fig. 265 shows the corresponding contact twin. Fig. 266 shows an interpenetrating so-called "Carlsbad" twin of orthoclase.

Twinning plane the Basal Pinacoid.

Fig. 267 shows the so-called "Manebacher" twin of orthoclase.

FIG. 266.

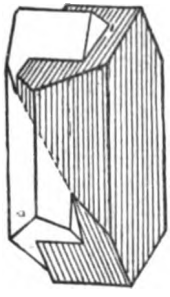


FIG. 267.

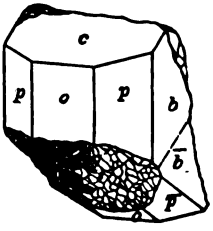
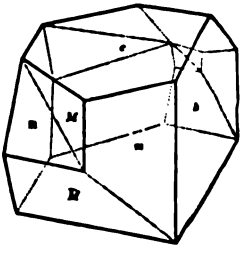


FIG. 268.



Twinning Plane a Dome Face.

Fig. 268 shows the so-called "Baveno" twin of orthoclase, the twinning plane being parallel to the clinodom $\infty \breve{a} : b : 2c$.

TRICLINIC TWINS.

Twinning Plane the Brachy Pinacoid.

Although any face may be a twinning plane, the brachy pina-

FIG. 269.

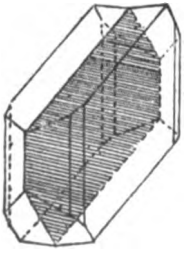
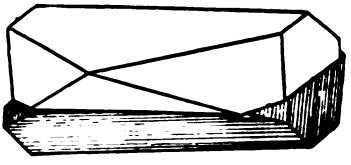


FIG. 270.



coid is the most frequent. Fig. 269 shows a twin of albite (albite law) the twinning plane shaded.

In the so-called pericline twin of albite the macro axis is the twin axis, Fig. 270. Twins also occur with the macro pinacoid as the twinning plane.

CHAPTER IX.

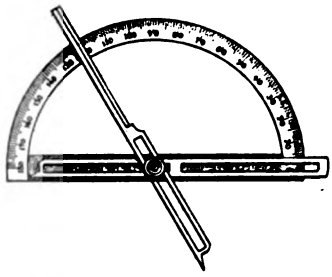
MEASUREMENT OF CRYSTAL ANGLES.

The instruments used in measuring the angles between crystal faces are called *goniometers.*

Hand Goniometers.

The hand-goniometer consists essentially of two pivoted arms and a graduated arc. If the crystal faces permit close contact, an instrument with detachable arms, like that shown in Fig. 271, will yield measurements which are accurate within one degree.

FIG. 271.



The arms are first lifted from the arc and slid upon the pivot until the pointed ends are of convenient, but not necessarily equal, length to be applied to the crystal. These ends are then so placed that each is perpendicular to the edge of intersection of the two crystal faces, and in such close contact that no light passes between the arms and the faces. When satisfactory adjustment has been secured the arms are clamped and replaced on the arc, as in the figure, and the angle is read. In the figure the angle is 120 degrees.

Several measurements should be made and the average taken. After each reading the arm should be unclamped and the new measurement made as if it were a different angle.

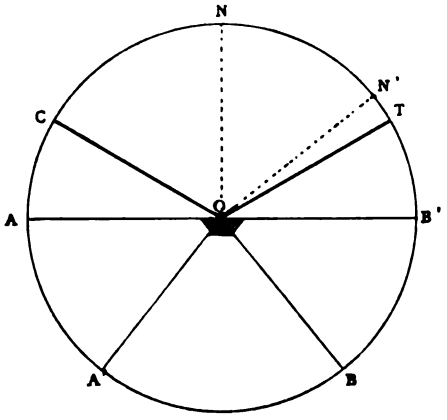
Reflection Goniometers.

The angles between smooth bright faces can be measured to half minutes or even closer, as follows:

The crystal is adjusted so that an edge coincides with the axis of rotation *O*, Fig. 272. *CO* is a ray of light fixed in direction. *TO* is the line of sight or axis of a telescope. *NO* bisects the angle *COT*.

Whatever the position of the crystal the ray *CO* striking it is lected, but only when a face of the crystal coincides with *AB'*, right angles to *NO*, can e reflection enter the fixed escope *OT*. For a posi- n of the crystal indicated the black rhomb, one ce coincides with *AB'*, d a reflection reaches *T*. nother face at that time incides with *OB*. A re- ction will be obtained om this second face, after rotation measured by the c *BB'*, the supplement of e arc *AB*, which measures e angle between the faces.

FIG. 272.



The axis of rotation may be horizontal, as in the Wollaston and itscherlich instruments, or vertical as in the Babinet and Fuess struments.

FIG. 273.

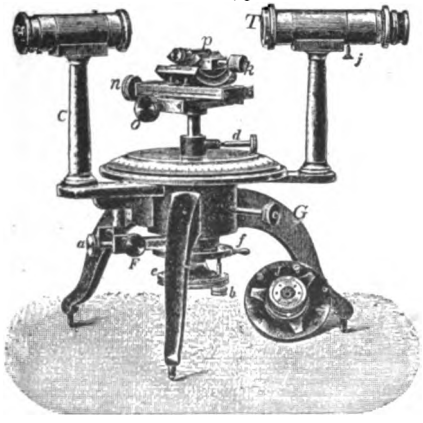


Fig. 273 shows the Fuess goniometer * (Model 4, a) which is dmirably adapted for student work. It is very much lower priced an the Model 2, but is exceedingly simple in adjustments and ccurate in its results.

* R. Fuess, Steglitz, near Berlin, marks 260, or about 65 dollars.

Two telescopes are used:

(*a*) The collimator telescope *C* fixed in a constant position and designed simply to guide to the crystal a ray of light from a lamp set at the outer end. At this end is an orifice like a double crescent, Fig. 274, formed by two circular discs of equal diameter set a distance apart which can be regulated by a screw.

(*b*) The observation telescope *T*, which may be set at any desired angle to *C*, though the axes of *T* and *C* always remain in a horizontal plane and intersect in the axis of rotation. Within *T* are two cross hairs, one vertical, the other horizontal, adjusted to intersect in the axis of the telescope. The vertical cross hair is parallel to the axis of rotation.

Before the objective swings an extra lens which, when down, converts the telescope into a weak microscope, and brings the crystal into focus. When raised the crystal is out of focus, the telescope now being focused upon the light.

The crystal carrier is shown between the telescopes. The crystal is attached by wax to the plate at *p*. The extra lens is dropped and the crystal raised, or lowered, into the field by unclamping *d*. The desired edge is then successively *tipped* into vertical position by the two circular arcs below *p*, and centered, that is made to coincide with the vertical cross hair, by the sliding motions produced by the screws *n* and *o*.

During centering one of the centering slides should be placed at right angles to the telescope axis while the crystal edge is made coincident with the vertical cross hairs. The other centering slide should then be placed at right angles to the telescope axis and the coincidence again produced and this repeated until, during a rotation, the edge and vertical hair appear to be one, and on raising the extra lens the image of the signal from either face is symmetrically bisected by the cross hairs.

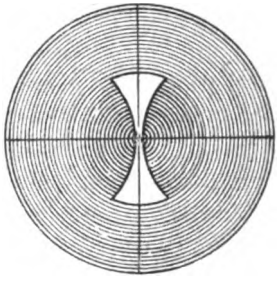
After centering the crystal edge the measurement is made as follows:

The telescope is set at some convenient angle to the collimator (100 to 120 degrees) by unclamping *G* which is then reclamped. The screw *a* is then unclamped, the graduated circle and crystal are turned together by the pilot-wheel *f*, until the reflected signal is seen through the telescope, then *a* is tightened, the signal moved by the tangent screw *F* until it is bisected by the vertical cross hair, as in Fig. 274, and the vernier is read and recorded.

The screw *a* is again loosened and the rotation continued until the signal is received from a second face, and this is centered by *F* and *a* and recorded as before and the difference between the two readings is the supplement angle.

At least three measurements of any angle should be made and preferably with different portions of the circle. For the second measurement when the signal from the second face is centered the screw *b* is loosened and the crystal alone is turned by the disk *e* until the signal from the first face is centered, then *b* is tightened and *a* loosened and the crystal and circle turned together as before. This is repeated before a third measurement.

FIG. 274.



The fundamental necessity for good measurement * is a good crystal with bright smooth faces. This is more apt to be found among little crystals than large ones. During and before measurement the crystal must not be touched with the fingers but handled with pincers and should be carefully cleaned with chamois skin.

* For greater detail in measurement see Characters of Crystals, by A. J. Moses, Chapter V.

CHAPTER X.

CRYSTAL PROJECTION OR DRAWING.

For description and illustration crystals are usually projected upon a vertical plane by parallel rays oblique to the plane of projection. The eye is conceived to be at an infinite distance but a little to the right and above the center of the crystal.

The figures obtained in this way have an appearance of solidity, all parallel edges are parallel in the projection and all points in a given line remain the same *proportionate* distances apart.

Construction of "Axial Cross."

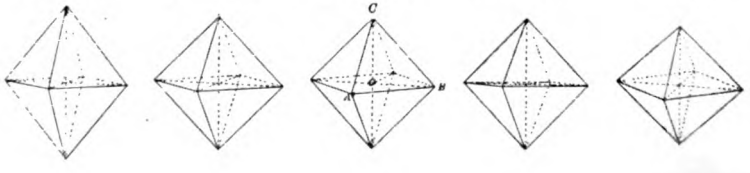
A definite relation exists between the projected lengths and angles of the isometric axes and the angles of elevation and rotation to the right of the line of sight.

The following table gives a series of projections, of which number 3 has been used in preparing the figures in this book (see Fig. 277):

	Angles between projected Axes.		Foreshortened lengths of axes for true length = 1.			Approximate Proportionate Lengths.		
	AOC	*BOC*	*OA*	*OB*	*OC*	*OA*	*OB*	*OC*
1	108° 19′	92° 06′	.239	.828	.994	29	100	120
2	110° 34′	92° 23′	.338	.950	.992	36	100	105
3	116° 17′	93° 8′	.353	.950	.986	37	100	104
4	96° 23′	90° 47′	.333	.944	.998	6	17	18
5	133° 24′	93° 11′	.324	.973	.973	1	3	3

Figs. 275, 276, 277, 278, 279 show these projections in order and the octahedron with each.

FIG. 275. FIG. 276. FIG. 277. FIG. 278. FIG. 279.



tragonal Axial Cross.

To construct the axial cross of a tetragonal crystal OA and OB the isometric cross, Fig. 277, are unchanged but OC is multi-ed by the unit value c for the particular crystal. Thus if $c = 0.64$ half vertical axis is drawn sixty-four one-hundredths of the gth of OC.

thorhombic Axial Cross.

The directions of OA, OB, OC, are unchanged. OB is unchanged ength; OA is multiplied by the stated unit value for $\breve{a}$, and OC the stated unit value for c. Thus in barite with $\breve{a} : \bar{b} : c =$ 15 : 1 : 1.313 OB is unchanged, OA is made aproximatley ht-tenths of its isometric length and OC is made approximately e and one-third times its isometric length.

noclinic Axial Cross.

n this system one of the axes has a different inclination to the responding isometric axes. To obtain this *direction* in the per-ctive proceed as follows:

Upon the isometric axes $A\bar{A}$, $B\bar{B}$, $C\bar{C}$, Fig. 280, lay off $Or = OC$ β and $On = OA \sin \beta$. Complete the parallelogram $OrDn$; n is DD the projection of a line equal in length than an isometric s but in the *direction* of the desired clino axis.

OD is then multiplied by the value of $\dot{a}$ and OC by the value of s in the orthorhombic.

FIG. 280.

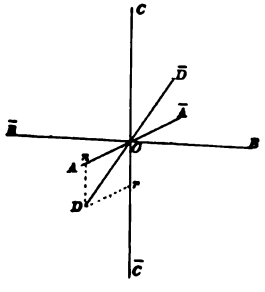
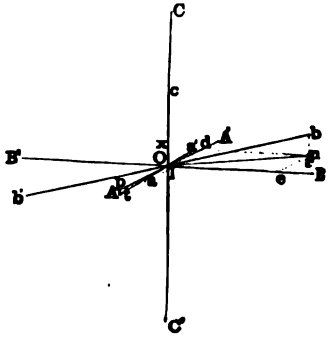


FIG. 281.



iclinic Axial Cross.

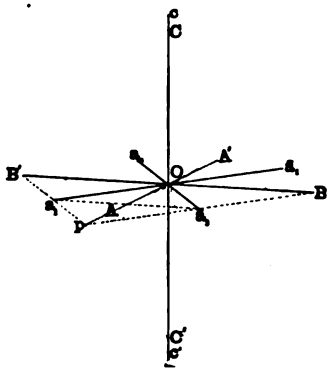
In this, Fig. 281, the same method is carried further, for in-nce: The constants for axinite are $\breve{a} : \bar{b} : c = 0.492 : 1 : 0.479$, $\wedge\, c = \beta = 91° 52'$, $b \wedge c = \alpha = 82° 54'$, $a \wedge b = \gamma = 131° 39'$.

Vertical Axis.—Make $Oc = OC \times .479$.

Macro Axis.—Make $Oe = OB \sin 131° 39'$, and $Od = OA \cos 131° 39'$; complete the parallelogram *dOen*. Make $Or = On \sin 82° 54'$ and $Ox = OC \cos 82° 54'$; complete the parallelogram *rOxb*. Then is *Ob* the projection of one-half the desired axis.

Brachy Axis.—Make $Ol = OC \cos 91° 52'$, and $Op = OA \sin 91° 52'$. Complete the parallelogram *pOlt*; make $Oa = 0.492 = Ot$; then is *Oa* the projection of one-half the desired axis.

FIG. 282.



Hexagonal Axial Cross.

The proportionate value of *c* is laid off on *CC'* and the basal axes are derived as follows: Fig. 282.

Make $Op = OA \times 1.732$; draw *pB* and *pB'*; bisect *Op* by a line parallel to *BB'*; then are *OB*, *Oa* and Oa_3 the projections of desired semi-axes.

Determination of the Direction of Edges.

The unit form is obtained by joining the extremities of the axial cross by straight lines, and other simple forms are easily drawn by methods which suggest themselves; for instance, the unit prism by lines through the terminations of the basal axes parallel to the vertical axis. It is always possible, also, to obtain two points of any edge by actually constructing the two planes and finding the intersection of their traces in two axial planes. The method, however, is cumbersome.

In all systems the projected intersections of *any* planes may be simply found by the following method:

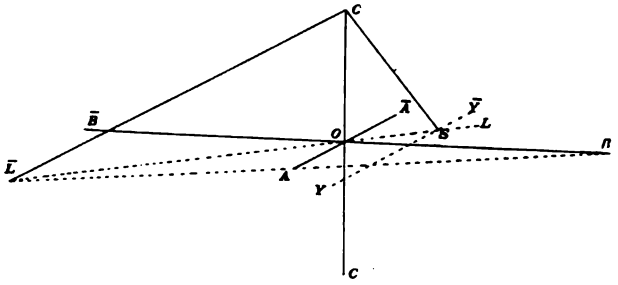
After obtaining the *axial cross* of the crystal, every plane on the crystal is assumed to be moved parallel to itself until it cuts the vertical axis *c* at unity; the new planes all pass through the extremity of *c* and that point is therefore common to all lines of intersection.

Another point of each line or direction of intersection will be the intersection of the traces of the two planes on the plane of the basal axes. If the symbol of each plane is reduced until $c = 1$, the values of the intercepts on *a* and *b* result, and the traces of the planes are thus found and the desired points are the intersections of these traces.

The method will be sufficiently illustrated by following in detail ne construction for the intersections of l, y and p of the topaz rystal, Fig. 284.

In Fig. 283, $A\bar{A}$, $B\bar{B}$ and $C\bar{C}$ form the projected axial cross of opaz. The faces l, y and p are respectively $2a : b : \infty c$, $\infty a : b : 4c$

FIG. 283.



nd $a : b : c$. If these are moved each parallel to itself until they ntersect c at unity their symbols (obtained by dividing by the oefficients of c in each case) will be $0a : 0b : c$, $\infty a : \frac{1}{4}b : c$, $a : b : c$.

Their traces upon the plane AOB, ig. 283, will be therefore respectively:

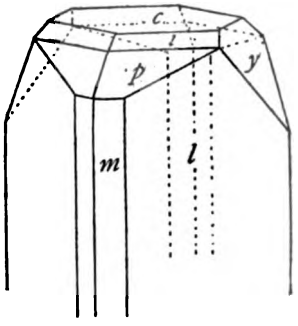
For l, the line $L\bar{L}$ through the center ut parallel to its former position at hich it cut at $2a$ and b.

For y, the YY parallel $A\bar{A}$ and inter- ecting at one-fourth b.

For p the line AB intersecting at a nd b.

The lines $L\bar{L}$ and YY intersect at S; herefore SC is the direction of intersec- on of l and y.

FIG. 284.



The lines $L\bar{L}$ and AB intersect at L; therefore LC is the direc- on of intersection of l and p.

All other intersections may be obtained in the same manner on ny axial cross.

onstruction of the Figure.

The edge directions thus found are now to be united in ideal ymmetry, yet so as to show, as far as possible, the relative de- elopment of the forms.

A second axial cross is drawn parallel to that used in determin-

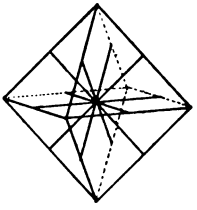
ing the edge directions and these are transferred by triangles, care being taken that all corresponding dimensions are in their proper proportions and in accord with the planes of symmetry. Generally it will be best to pencil in and verify the principal forms and later, to work in the minor modifying planes.

The back (or dotted) half of most crystals can be obtained by marking the angles of the front half on tracing paper, turning the paper in its own plane 180° and pricking through. This is also a test of accuracy, for the outer edges, angle for angle, should coincide.

Special Construction with Isometric Simple Forms.

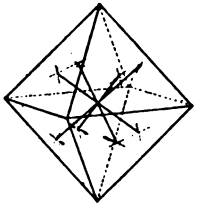
The vertices of all solid angles in isometric forms are either points on the crystallographic axis, or points on the diameter E connecting the centers of the opposite edges of the octahedron, Fig. 285. Or finally upon the diameters F connecting the centers of opposite faces of the octahedron, Fig. 286.

FIG. 285.



Diameter E.

FIG. 286.



Diameter F.

In any form, $a : na : ma$ the vertices desired are obtained by lengthening the diameters E and F as obtained in Figs. 285 and 286 by the proportions obtained by the following formulas:

$$Increase\ F = \frac{2mn - (m+n)}{mn + (m+n)}.$$

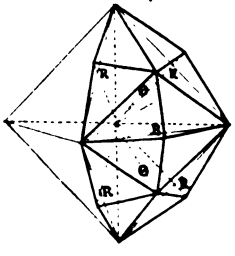
$$Increase\ E = \frac{n-1}{n+1}.$$

For instance, the hexoctahedron $a : \frac{3}{2}a : 3a$, shown in Fig. 26, as the values $m = 3$ and $n = \frac{3}{2}$ hence

$$Increase\ F = \frac{2 \times 3 \times \frac{3}{2} - (3 + \frac{3}{2})}{3 \times \frac{3}{2} + (3 + \frac{3}{2})} = \frac{1}{2}.$$

$$Increase\ E = \frac{\frac{3}{2} - 1}{\frac{3}{2} + 1} = \frac{1}{5}.$$

FIG. 287.



As illustrated in Fig. 287, the diameters F normally terminating at the points O, have been extended $\frac{1}{2}$, and the diameters E normally terminating at the points R, have been extended $\frac{1}{5}$, and the resulting points connected by lines forming the figure.

For inclined hemihedral forms:

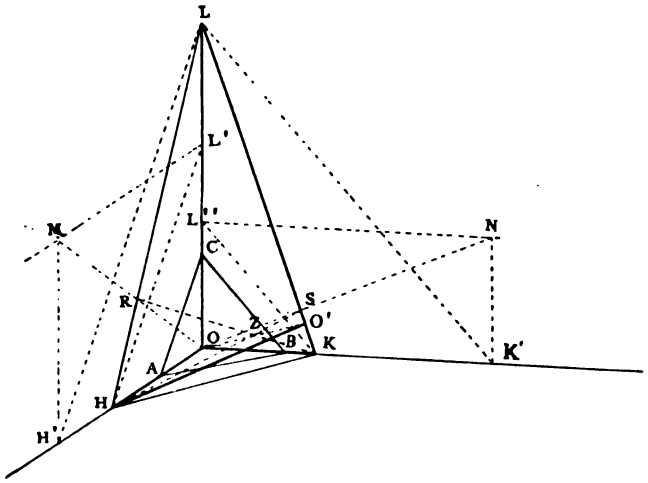
$$Increase\ F = \frac{2mn - (m-n)}{mn + (m-n)}.$$

'win Crystals.

To find the axes of the form which is in reverse position, the fol-owing construction may be used.

Let OA, OB, OC, Fig. 288, be the axial cross of the normal crystal nd HKL the twinning plane. To find first the point Z at which ne normal from O cuts HKL, draw $H'L$ and HL' parallel AC nd draw KL'' and $K'L$ parallel BC. Complete the parallelograms

FIG. 288.



$OH'ML'$ and $OK'NL''$ and draw their diagonals OM and ON and from the intersections of these with HL and LK draw RK and SH respectively; their intersection is the desired point Z.

Prolong OZ till $ZO' = OZ$, then is O' the center of axes for the second crystal and, as the face HKL is common, $O'H$, $O'K$ and $O'L$ are in direction and length are the coördinates of this face on the new axes.

The unit lengths will be found by drawing AA', BB' and CC' parallel to $O'Z$.

All constructions on the axes of the second crystal follow the rules previously given.

PART II.

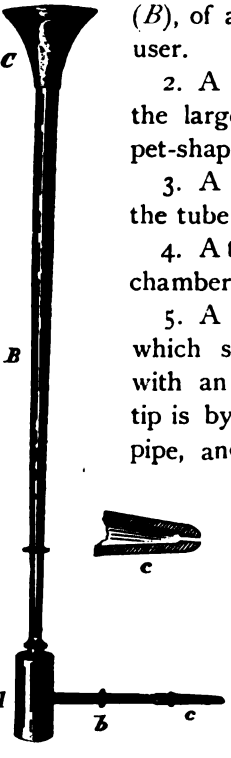
BLOWPIPE ANALYSIS.

CHAPTER XI.

APPARATUS, BLAST, FLAME, ETC.

The Blowpipe.

FIG. 289.



The best form of blowpipe (Fig. 289) consists of:

1. A tapering tube of brass or German silver (*B*), of a length proportionate to the eyesight of the user.

2. A horn or hard rubber mouthpiece (*C*) at the larger end of the tube; which is best of trumpet-shape to fit against the lips.

3. A moisture chamber (*A*) at the smaller end of the tube connected by ground joints to

4. A tapering jet (*b*) at right angles to the moisture chamber.

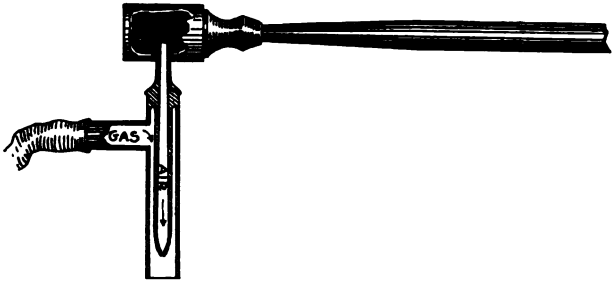
5. A tip of platinum or brass (*c*), shown enlarged, which should be bored from a solid piece, and with an orifice of 0.5 millimeter diameter. The tip is by far the most important part of the blowpipe, and, if correctly made, the flame produced will be perfectly regular and will not flutter.

When not in use the blowpipe should be so placed that the tip is supported free from contact. If the tip is clogged by smoke or otherwise it should be burned out or cleaned with the greatest care so as not to injure the regular form of the orifice.

Gas Blowpipe.

For most purposes the gas blowpipe, Fig. 290, is a convenient form and is extensively used. The flame is not quite so hot as

FIG. 290.



that from rape-seed oil, but is sufficient to round the edges of a calamine splinter. Oxidation and reduction are easily obtained and the cleanliness and ease of control cause it to be preferred by many. The ordinary blowpipe can be made into a gas blowpipe by means of an attachment to connect to the moisture chamber.

Blowpipe Lamps.

Bunsen Burner.—The simplest form of lamp for laboratory pur-

FIG. 291.

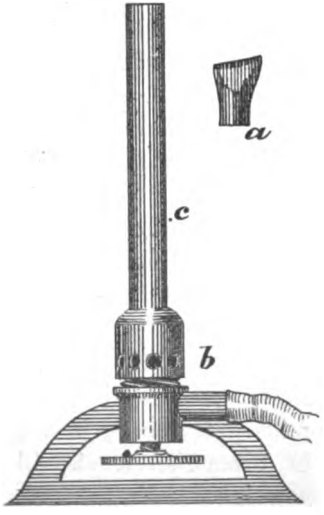
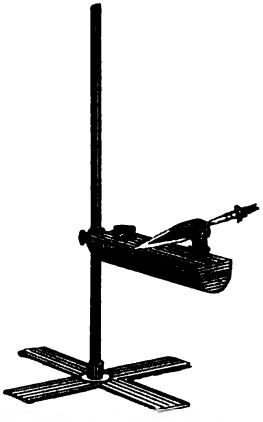


FIG. 229.



poses is the ordinary *Bunsen* burner, Fig. 291, using gas and furnished with a special top or an inner tube (*a*), shaped to spread

flame. When used with the blowpipe the orifices (*b*) at the tom of the burner should be closed, so that no air enters with gas. A flame about 4 cm. high gives the best results.

The hottest flame and greatest variations in quantity and quality flame are obtained from oils rich in carbon, such as refined rape-d, or olive or lard oil, or from mixtures of turpentine and alco-. These can be used in the field and where gas is not available. some kinds of blowpipe work they are to be preferred to gas, will not serve for bending glass or for heating without the wpipe.

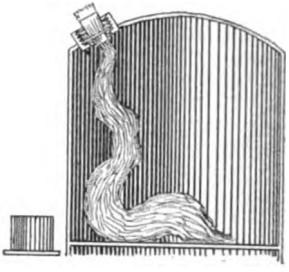
Berzelius Lamp.—A lamp with two openings, Fig. 292, is gen-lly used for oil.

The wick should be soft, close-woven and cylindrical, such as sed with Argand lamps. It should be folded and inserted with opening toward the lower side of the brass holder.

To fill the lamp both caps are removed and the oil poured in ough the smaller orifice. During work, the smaller cap is hung the vertical rod; the larger is placed over the smaller orifice sely, keeping out the dust, but admitting the needed air.

The lamp is lighted by blowing a flame and across the wick. When well arred, the wick is carefully trimmed rallel to the brass holder.

FIG. 293.



Fletcher Lamp.—The Fletcher blow-pe lamp, Fig. 293, gives good satisfac-n, and a modified form, burning solid s, tallow or paraffine, is especially apted for field work.

pports of Charcoal, Plaster, Etc.

Charcoal.—Charcoal made from soft woods, such as willow or ne, is used to support the substance and receive any coats or blimates that may form, and, in a measure, is a reducing agent. convenient size is 4 inches long, 1 inch broad, and $\frac{5}{8}$ inch thick.

Plaster.—Plaster tablets are used for the same purpose. These e prepared by making a paste of plaster of Paris and water, just ick enough to run, which is spread out upon a sheet of oiled ass and smoothed to a uniform thickness ($\frac{1}{8}''$ to $\frac{1}{4}''$) by another naller sheet of glass, which may be conveniently handled by gum-ing a large cork to one side and using it as a plasterer's trowel.

While still soft, the paste is cut *through* with a knife into uniform slabs, 4″ by 1½″. It is then dried, after which the tablets are easily detached.

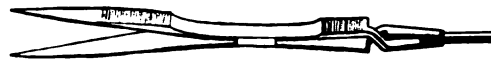
Aluminum and Glass.—Ross used supports of aluminum plate and recently Goldschmidt has recommended catching the sublimates on glass plates upon which they can be microscopically examined or submitted to wet treatment.

Miscellaneous Apparatus:

Each student should have at his desk, in addition to blowpipe, blowpipe-lamp, charcoal and plaster:

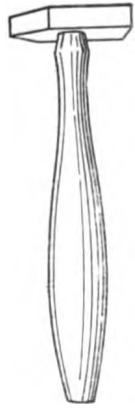
Forceps, with platinum tips for fusion tests. The most convenient form is shown, Fig. 294, the platinum ends projecting at least three-fourths of an inch.

Fig. 294.



Platinum Wire and Holder.—Wire of the thickness of about 24 Am. standard wire gauge. The handle for holding this is sometimes only a short piece of small glass tubing, into the end of which the wire is fused. A holder in which the wires can be changed and with a receptacle for a stock of wires, is more convenient.

Fig. 295.



Reagent Bottles.—Four 2-oz. wide-mouthed bottles; for borax, soda, salt of phosphorus, and bismuth flux will be needed at all times. It is better to have at least eight such bottles in a convenient stand.

Anvil.—Slab of polished steel, about 1½″ by 1½″ by ½″.

Hammer.—Steel, with square face, ⅜″ or ½″. As in Fig. 295.

Closed Tubes or Matrasses.—

Cupel Holder and Cupels, for silver determination.

Less essential are:

Bar magnet, with chisel edge.

Trays, for dirt and for charcoal.

Lens, knife, and watch glasses.
Blue and green glasses.
Steel forceps and lamp scissors for trimming wick.
Cutting pliers, for cutting bits from minerals to be tested.
Agate mortar and pestle. Can be obtained 1¼″ in diameter.
Small porcelain dishes, ivory spoon, dropping tube.

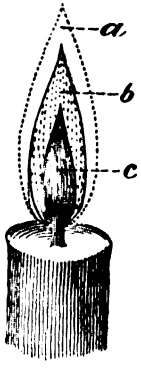
BLAST AND FLAME.

The Blast.

The blast is produced by the muscles of the distended cheeks, and not by the lungs.

It is best to sit erect, with the blowpipe held lightly but firmly in the right hand, and with the elbows against the sides. Then, with the cheeks distended and the mouth closed, place the mouth-piece against the lips, breathe regularly through the nose, and allow air to pass into the pipe through the lips. From time to time, as needed, admit air to the mouth from the throat. In this manner a continuous blast can be blown without fatigue, after learning, by practice, to breathe through the nose while keeping the cheeks continually distended.

FIG. 296.



The Flame.

A LUMINOUS FLAME (Fig. 296) usually shows three distinct portions.

1. A very hot non-luminous veil, *a*, of carbon dioxide and free oxygen.

2. A yellow luminous mantle, *b*, of burning gases and incandescent carbon.

3. An interior dark cone, *c*, of unburned gases, not always visible.

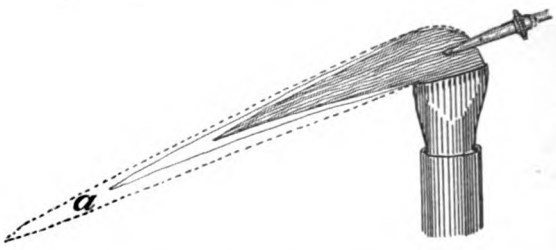
Oxidation and Oxidizing Flame.

The oxidizing flame is non-luminous, for luminosity indicates unconsumed carbon, and hence a more or less strongly reducing action.

To produce such a flame, place the tip of the blowpipe almost touching the top of the burner, or the wick, and, extending in ⅓ the breadth of the flame, blow parallel to the burner top or wick until there is produced a clear blue flame nearly an inch long. This blue flame is itself weakly reducing,

but just beyond at *a* (Fig. 297) is an intensely hot, nearly colorless zone, which is strongly oxidizing, and the bead is held

FIG. 297.



in this usually as far from the tip of the blue flame as the bead can be kept fluid. If the substance to be oxidized is supported on charcoal, a weak blast must be used.

FIG. 298.

With the gas blowpipe all that is necessary is to avoid an excess of gas. The blue flame is, as before, surrounded by the oxidizing colorless mantle.

Testing Purity of Oxidizing Flame.—A loop, Fig. 298, about 3 mm. in diameter, is made in platinum wire by bending it around a pencil point, or with the forceps, so that the end meets but does not cross the straight part. This loop is heated and dipped into the flux, and the portion of flux that adheres is fused to a clear bead, more being added until the bead is of good full shape.*

Molybdic oxide, MoO_3, is then dissolved in the bead at the tip of the blue flame, giving a brown to black bead from production of MoO_2 but, if moved to *a*, Fig. 297, the color is readily removed by the reoxidation of the MoO_2 and the bead made colorless.

Reduction and the Reducing Flames.

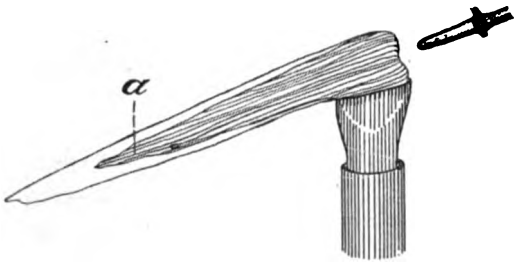
To blow the yellow reducing flame, Fig. 299, place the tip of the blowpipe one-eighth of an inch above and back of the middle of the flame, blow strongly parallel to the burner top or wick, and turn the entire flame in the direction of the blast.

The blast must be continuous; too strong to produce a sooty flame, and not strong enough to oxidize by excess of air.

* When the flux is salt of phosphorus, the wire should be held over the flame so that the ascending hot gases will help to retain the flux upon the wire.

e blue flame also is reducing because of the carbon monoxide tains, but the quantity is not large enough to be generally ve.

FIG. 299.



th the gas blowpipe reduction is obtained by using a larger and inserting the bead within the blue; or with large excess s a yellow reducing flame may be obtained.

sting Purity of Reducing Flame.—Manganese dioxide, MnO_2, solved in a borax bead in the oxidizing flame; if only a little ed the bead is violet red when cold, and may be made color- n the reducing flame. Or cupric oxide or oxide of nickel may ssolved in a borax bead until the bead is opaque, and then ed on charcoal to a clear bead and a metallic button.

CHAPTER XII.

OPERATIONS OF BLOWPIPE ANALYSIS.

Fusion.

THE hottest portion of the flame is just beyond the tip of the blue flame. In some instances, noticeably certain iron ores, substances infusible in the oxidizing flame are fusible in the reducing flame.

The test will be differently made, according to the material.

(*a*) If metallic or reducible, treat in a shallow hole on charcoal, using a fragment of the substance the size of a pin's head.

(*b*) If stony or vitreous, treat a small sharp-edged fragment in the platinum forceps, at the tip of the blue flame, directing the flame upon the point.

(*c*) If in powder, or with a tendency to crumble, grind and mix with water to fine paste, spread thin on coal and dry, and, if coherent, hold in the forceps. If not coherent dip a moistened platinum wire in the powder, and treat the adhering powder in the flame.

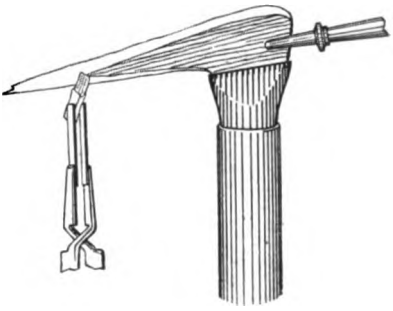
There will be noted both the *degree* of fusibility and manner of fusion.

The *degree* of fusibility is stated in much the same way as the hardness by comparing it with a scale of fusibility. It is generally, however, sufficient to class a mineral as simply easily fusible, fusible, difficultly fusible, or infusible. For purposes of comparison, the following scale, suggested by v. Kobell, is usually adopted:

1. *Stibnite*, coarse splinters fuse in a candle flame.
2. *Natrolite*, fine splinters fuse in a candle flame.
3. *Garnet* (*Almandite*), coarse splinters easily fuse before the blowpipe.
4. *Actinolite*, coarse splinters fuse less readily before the blowpipe.
5. *Orthoclase*, only fused in fine splinters or on thin edges before the blowpipe.
6. *Calamine*, finest edge only rounded in hottest part of flame.
7. *Quartz*, infusible, retaining the edge in all its sharpness.

The trial should always be made on small and fine pointed fragnts. Penfield recommends using a standard size about 1 mm. diameter and 4 mm. long. The fragment should project beyond platinum as in Fig. 300, so t heat may not be drawn off the platinum, and the flame ected especially upon the point. s always well to examine the nter with a magnifying glass, ore and after heating, to aid eye in determining whether edges have or have not been nded by the heat.

Fig. 300.



The manner of fusion may be h as to result in a glass or slag ch is clear and transparent, or white and opaque, or of some or, or filled with bubbles. There may be a frothing or intuscence, or a swelling and splitting (exfoliation). In certain inces the color and form may change without fusion, etc.

Flame Coloration.

During the fusion test the non-luminous veil is sometimes unnged, but it is often enlarged and colored by some volatilizing stituent. There is frequently a bright yellow coloration due to ium salts, but this gives place to the color proper.

The flame is best seen in a dark room or against a black backund, such as a piece of charcoal, and is often improved by drochloric acid and occasionally by other reagents.

Some elements color the flame best at a gentle heat, others only the highest heat attainable. A good method to cover all cases o dip the end of a flattened platinum wire first in hydrochloric d and then in the finely powdered substance and hold it first in mantle flame near the wick and then at the hottest portion at tip of the blue flame. It is possible in this way to obtain two tinct flames such as the red of calcium and the blue from cop- chloride.

The colors can also often be seen to decided advantage by ply holding the wire in the non-luminous flame of a Bunsen rner or even in the flame of an alcohol lamp.

Flame tests for Ca, Sr and Ba are not usually obtainable from cates.

The important flame colorations are :

Yellows.

YELLOW.—Sodium and all its salts. Invisible with blue glass.

Reds.

CARMINE.—Lithium compounds. Masked by soda flame. Violet through blue glass. Invisible through green glass.

SCARLET.—Strontium compounds. Masked by barium flame Violet red through blue glass. Yellowish through green glass.

YELLOWISH.—Calcium compounds. Masked by barium flame. Greenish gray through blue glass. Green through green glass.

Greens.

YELLOWISH.—Barium compounds, molybdenum sulphide and oxide ; borates especially with sulphuric acid or boracic acid flux.

PURE GREEN.—Compounds of tellurium or thallium.

EMERALD.—Most copper compounds without hydrochloric acid.

BLUISH.—Phosphoric acid and phosphates with sulphuric acid.

FEEBLE.—Antimony compounds. Ammonium compounds.

WHITISH.—Zinc.

Blues.

LIGHT.—Arsenic, lead and selenium.

AZURE.—Copper chloride.

WITH GREEN.—Copper bromide and other copper compounds with hydrochloric acid.

Violet.

Potassium compounds. Obscured by soda flame. Purple red through blue glass. Bluish green through green glass. In silicates improved by mixing the powdered substance with an equal volume of powdered gypsum.

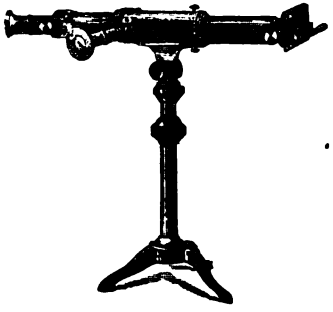
USE OF THE SPECTROSCOPE.

When salts of the same metal are volatilized in the non-luminous flame of a Bunsen burner the spectra produced on decomposing the resultant light by a prism will show lines identical in color, number and relative position. Salts of different metals will yield different lines.

Although, with pure salts, the already described flame colorations are generally distinct and conclusive, it will frequently happen that in silicates or minerals containing two or more reacting

bstances the eye alone will fail to identify the flame coloration. is well therefore to supplement the ordinary flame tests by ectroscopic observation. In the blowpipe laboratory the chief e of the spectroscope will be to identify the metals of the potas- ım and calcium families singly or mixtures. For this purpose the rect vision spectroscope of Hoff- an, Fig. 301, is perhaps the most nvenient.

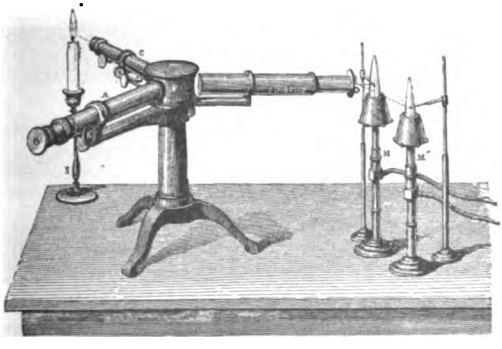
Fig 301.



The substance under examination ould be moistened with hydro- loric acid and brought on a plati- ım wire into the non-luminous flame the Bunsen burner as in the ordi- ry flame test. In viewing the flame rough the properly adjusted spec- oscope certain bright lines will be seen, and by comparing these th the chart, Fig. 304, or with substances of known composition, e nature of the substance may be determined. The sodium line ll almost invariably be present and the position of the other es will be best fixed by their situation relative to this bright llow line.

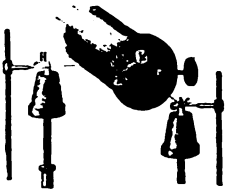
The more ordinary form of spectroscope, Fig. 302, has special dvantages in allowing an easy comparison of flames. *A* is the

Fig. 302.



bservation telescope, *B* the collimator through which the light om the flames *M* and *M'* is sent as parallel rays through the prism to the telescope *A*. The third telescope *C* sends the image of

FIG. 303.

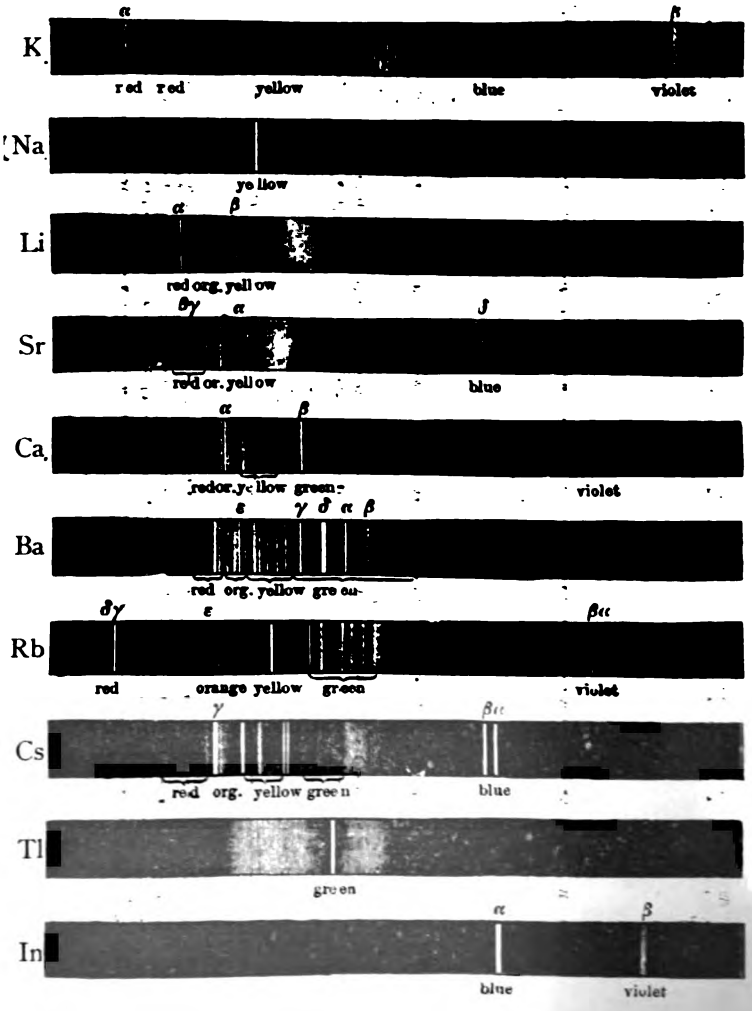


a micrometer scale to *A* by which the relative distance apart of the lines is judged.

Fig. 302 shows an enlarged view of the collimator *B*. By means of the little rectangular prism *i* the light from a second flame *H* placed at one side is sent through the collimator and its spectrum obtained side by side with that from the flame *G*.

In this manner the spectrum of an unknown substance may be compared with that of one of known composition and if lines

FIG. 304.



he unknown coincide with those of the known substance the tity of at least one of its constituents is established.

he chart (Fig. 304) and brief description of spectra of substances ng distinct lines with the Bunsen flame will be of service.

ASSIUM—two red lines and one violet line.

IUM—a single bright yellow line, which with higher dispersion is resolved into two lines. Almost always present from the small amounts of sodium in dust.

HIUM—one very bright deep red line and a faint line in the orange.

ONTIUM—a number of characteristic red lines and one blue line.

CIUM—a bright red, and a bright green line, with fainter red to yellow lines and a line in the violet.

IUM—a number of yellow and green lines.

IDIUM—two violet and two red lines with several less prominent lines in the orange, yellow and green.

SIUM—two distinct blue lines and one orange line.

ALLIUM—one characteristic green line.

IUM—an indigo blue line and a violet line.

VOLATILIZATION.

n blowpipe analysis, antimony, arsenic, cadmium, zinc, tin, , mercury and bismuth are always determined by securing limates of either the metals themselves or of some volatile de, iodide, etc.

Other elements and compounds, such as sulphur, selenium, telum, osmium, molybedenum, ammonia, etc., are also volatilized in part determined during volatilization as odors or by subates. Certain other compounds, particularly chlorides of sodium potassium and of some other metals, such as copper, tin and , yield sublimates ordinarily disregarded.

Volatilization tests are commonly obtained on charcoal, or ster or in open and closed tubes.

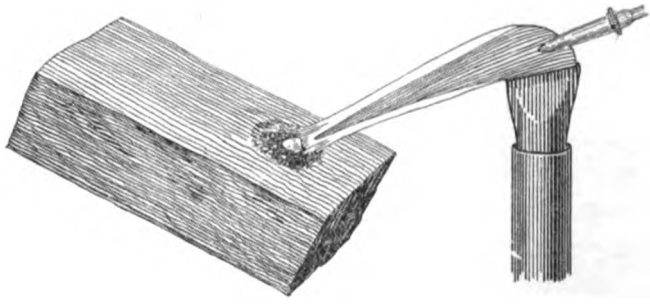
Treatment on Charcoal.

A shallow cavity, just sufficient to prevent the substance slipg, is bored at one end of the charcoal and a small fragment or ery little of the powdered substance is placed in it. The char-

coal is held in the left hand, so that the surface is at right angles to the lamp but tipped vertically at about 120° to the direction in which the flame is blown.

A gentle oxidizing flame is blown, the blue flame not touching the substance, but being just behind and in a line with it. After a

FIG. 305.



few moments the test is examined and all changes are noted, such as position and color of sublimates, color changes, odors, decrepitation, deflagration, formation of metal globules or magnetic particles. The heat is then increased and continued as long as the same reactions occur, but if, for instance, a sublimate of new color or position is obtained, it is often well to remove the first sublimate either by transferring the substance to another piece of charcoal or by brushing away the first formed sublimate after its satisfactory identification.

The same steps should then be followed using the reducing flame.

The sublimates differ in color and position on the charcoal ; some are easily removed by heating with the oxidizing flame, some by the reducing flame, some are almost non-volatile, and some impart colors to the flame.

Treatment on Plaster Tablets.

Experience has shown that the sublimates obtained on charcoal and plaster supplement each other. The method of using is precisely the same, and white sublimates are easily examined by first smoking the plaster surface by holding it in the lamp flame.

The coatings differ in position, and to some extent in color.

aster is the better conductor, condenses the oxides closer to the say, and therefore, the more volatile coatings are thicker and ore noticeable on plaster, while the less volatile coatings are ore noticeable when spread out on charcoal. Charcoal supple-ents the reducing action of the flame, and therefore is the better pport where strong reduction is desired.

Comparison of Important Sublimates on Charcoal and Plaster.*

Without Fluxes.—Treated First in O. F., then in R. F.

ARSENIC.—White volatile coat. On smoked plaster it is crystal-e and prominent; on charcoal it is fainter and less distinct, but e odor of garlic is more marked. Deposits at some distance om assay. Fumes invisible close to assay.

ANTIMONY.—White pulverulent volatile coat, more prominent on arcoal. Deposits near assay and fumes are visible close to assay er removal of flame.

SELENIUM.

On Charcoal.—Horse-radish odor and a steel-gray coat.

On Plaster.—Horse-radish odor, brick-red to crimson coat.

TELLURIUM.

On Charcoal.—White coat with red or yellow border.

On Plaster.—Deep brown coat.

CADMIUM.

On Charcoal.—Brown coat surrounded by peacock tarnish.

On Plaster.—Dark brown coat shading to greenish-yellow d again to dark brown.

MOLYBDENUM.—Crystalline yellow and white coat with an outer rcle of ultramarine blue. Most satisfactory on plaster.

LEAD.— } Yellow sublimate with outer fringe of white. More
BISMUTH.— } noticeable on charcoal than on plaster.

ZINC.—White, not easily volatile coat, yellow while hot. Best n charcoal.

TIN.—White non-volatile coat close to assay, yellowish while ot. Best on charcoal.

* Certain compounds give white coating before the blowpipe which at times cause fusion. Notably among these are many chlorides and the sulphate of lead. Among nerals, galena and other lead sulphides give a white sublimate which must not confused with arsenic or antimony coats.

II. With Bismuth Flux.*

LEAD.

On Plaster.—Chrome yellow coat.

On Charcoal.—Greenish-yellow, equally voluminous coat.

BISMUTH.

On Plaster.—Chocolate-brown coat, with an underlying scarlet; with ammonia it becomes orange-yellow, and later cherry-red.

On Charcoal.—Bright red band with a fringe of yellow.

MERCURY.

On Plaster.—Scarlet coat with yellow, but if quickly heated is dull yellow and black.

On Charcoal.—Faint yellow coat.

ANTIMONY.

On Plaster.—Orange coat stippled with peach-red.

On Charcoal.—Faint yellow coat.

ARSENIC.

On Plaster.—Yellow and orange coat, and not usually satisfactory.

On Charcoal.—Faint yellow coat.

TIN.

On Plaster.—Brownish-orange coat.

On Charcoal.—White coat.

The following tests show only on the plaster:

SELENIUM.—Reddish-brown, nearly scarlet.

TELLURIUM.—Purplish-brown with darker border.

MOLYBDENUM.—Deep ultramarine blue.

III. With Soda (Sodium Carbonate or Bicarbonate).

Soda on charcoal exerts a reducing action partly by the formation of sodium cyanide, partly because the salts sink into the charcoal and yield gaseous sodium and carbon monoxide. The most satisfactory method is to mix the substance with three parts of the moistened reagent and a little borax; then spread on the charcoal and treat with a good reducing flame until everything that can be absorbed has disappeared. Moisten the charcoal with water, break out and grind the portion containing the charge. Wash away the lighter part and examine the residue for scales and magnetic particles.

* Two parts of sulphur, one part of potassium iodide, one part of acid potassium sulphate.

'he reduction may result in:

. *Coating, but no reduced metal.*

Volatile white coating and garlic odor,	**As.**
Reddish-brown and orange coating with characteristic variegated border,	**Cd.**
Non-volatile coating, yellow hot and white cold,	**Zn.**
Volatile steel-gray coating and horseradish odor,	**Se.**
Volatile white coating with reddish border,	**Te.**

. *Coating with reduced metal.*

Volatile thick white coating and gray brittle button,	**Sb.**
Lemon-yellow coating and reddish-white brittle button,	**Bi.**
Sulphur-yellow coating and gray malleable button,	**Pb.**
Non-volatile white coating, yellow hot, and malleable white button,	**Sn.**
White coating, made blue by touch of R. F., and gray infusible particles,	**Mo.**

. *Reduced metal only.*

Malleable buttons,	**Cu, Ag, Au.**
Gray magnetic particles,	**Fe, Co, Ni.**
Gray non-magnetic infusible particles,	**W, Pt, Pd, Ir, Rh.**

'he carbonate combines with many substances forming both ble and infusible compounds. Many silicates dissolve with a e of the reagent, but with more are infusible; a few elements n colored beads with the reagent, especially on platinum.

'he residue left after heating may contain malleable metallic ds of copper, lead, silver, tin or gold. It may consist of a tle easily fusible button of bismuth, antimony, or the sulphide, enide or antimonide of some metal. It may be magnetic from presence of iron, cobalt or nickel or it may show an alkaline ction, when touched to moistened red litmus or turmeric paper, icating the presence of some member of the potassium or cal-m group of metals.

Infusible Compounds.—Mg, Al, Zr, Th, Y, Gl.

Fusible Compounds.—SiO_2 effervesces and forms a clear bead t remains clear on cooling if the reagent is not in excess.

TiO_2 effervesces and forms a clear yellow bead, crystalline and aque on cooling:

WO_3 and MoO_3 effervesce but sink in the charcoal.

Ba, Sr, Ta, V, Nb sink into the charcoal.

Ca fuses, then decomposes, and the soda sinks into the charcoal.

72583

Colored Beads.—Mn forms a turquois or blue-green opaque bead with soda on plantinum wire in oxidizing flame.

Cr forms a chrome-yellow opaque bead with soda on platinum wire in oxidizing flame, which becomes green in reducing flame.

Sulphur Reaction.—If a little of the residue, with some of the charcoal beneath, is taken up upon the point of a knife and placed upon a wet silver coin, the coin will be blackened if sulphur was present as a sulphide. Sulphates and other sulphur compounds will also give the same reaction after thorough fusion. The test should always be made on a fresh piece of charcoal.

IV. With Metallic Sodium.

Reducing effects which are obtained with soda only by hard blowing may be accomplished by the use of metallic sodium immediately and with the greatest ease. The metal should be handled carefully and not allowed to come in contact with water. It should be kept in small tightly closed bottles, and if kept covered with naphtha, which is not necessary, care should be taken that the the naphtha is not exposed to fire.

A piece of sodium about the size of an ordinary borax bead is cut off with a knife and hammered out flat. The powdered substance is placed upon the sodium, pressed into it and the whole moulded into a little ball with a knife blade. This sodium ball should not be touched with the fingers, for if some oxides are present, such as lead oxide, spontaneous combustion may take place. After placing the sodium ball on the charcoal it should be touched carefully with a match or with the Bunsen flame. A little flash ensues and the reduction is accomplished. The residue can now be safely heated with the reducing flame of the blowpipe, any reduced metal collected together and the sodium compounds volatilized or absorbed by the charcoal. When present in sufficient quantity, beads of the malleable metals can be obtained immediately from almost any of their mineral compounds ; metals like zinc and tin which require reduction before volatilization yield their sublimates with comparative ease ; and if a little of the charcoal beneath the assay is placed on a wet silver coin the sulphur reaction will be obtained if sulphur was present.

In general the results are the same as outlined for soda but are much more easily secured.

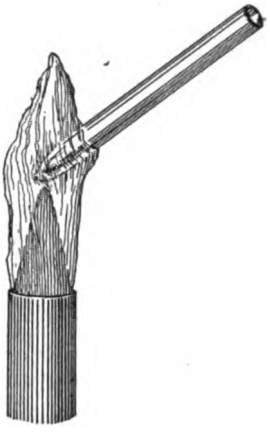
Even silica, silicates, borates, etc., are reduced but are generally identified by other means.

hese reactions are not successful on plaster tablets on account eir non-absorbent character.

Tests in Closed Tubes and Matrasses.

he matrass is practically a glass tube closed at one end and vn to a bulb. In most cases better results are secured by g a plain narrow tube about 4 inches ¼ inch and closed at one end. The l purpose is to note the effects of without essential oxidation; they also used for effecting fusions with reagents as $KHSO_4$ or $KClO_3$. nough of the substance is slid down arrow strip of paper, previously in- ed in the tube, to fill it to the height bout one-half inch; the paper is with- vn and the slightly inclined tube ed at the lower end gradually to a heat, Fig. 306. The results may evolution of water, odorous and non- rous vapors, sublimates of various rs, decrepitation, phosphorescence, fusion, charring, change olor, magnetization, etc.

FIG. 306.



d or alkaline moisture in the upper part of tube, . .	H_2O.
rless gas that assists combustion (nitrates, chlorates and per oxides), ...	O.
gent gas that whitens lime water, ...	CO_2.

Odors.

r of prussic aid, ...	CN.
r of putrid eggs, ...	H_2S.
r that suffocates, fumes colorless, bleaching action, .	SO_2.
r that suffocates, fumes violet, ...	I.*
fumes brown, ...	Br.
fumes greenish yellow, . .	Cl,
fumes etch the glass, . .	F.
r of nitric peroxide, fumes reddish-brown, .	NO_2.
r of ammonia, fumes colorless or white, . .	NH_3.†

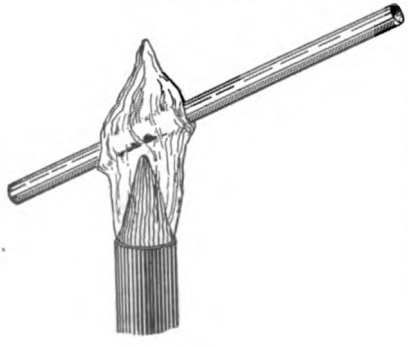
I, Br, Cl, F and N_2O_5 are assisted by mixing substance with acid potassium ate. †NH_3, Hg, As, Cd are asslsted by mixing with soda.

Sublimates.

Sublimate white, fusing yellow,	$PbCl_2$.
fusing to drops, disagreeable odor,	Os.
and volatile,	NH_4 (salts).
yellow hot, infusible,	HgCl.
yellow hot, fusible,	$HgCl_2$.
fusible, needle crystals,	Sb_2O_3.
volatile, octahedral crystals,	As_2O_3.
fusible, amorphous powder,	TeO_2.
Sublimate mirror-like, collects in globules,	Hg.
does not collect in globules,	As, Cd, Te.
Sublimate red when hot, yellow cold,	S.
Sublimate dark red when hot, reddish-yellow cold,	As_2S_3.
Sublimate black when hot, reddish-brown cold,	Sb_2S_3.
Sublimate black, but becomes red when rubbed,	HgS.
Sublimate red to black, but becomes red when rubbed,	Se.
Color of substances changes	
from white to yellow, cools yellow,	PbO.
from white to yellow, cools white,	ZnO.
from white to dark yellow, cools light yellow,	Bi_2O_3.
from white to brown, cools yellow,	SnO_2.
from white to brown, cools brown,	CdO.
from yellow or red to darker, after strong heat, cools green,	Cr_2O_3.
from red to black, cools red,	Fe_2O_3.
from blue or green to black, cools black,	CuO.

Tests in Open Glass Tubes.

FIG. 307.



By using a somewhat longer tube, open at both ends and held in an inclined position, a current of air is made to pass over the heated substance, and thus many substances not volatile in themselves absorb oxygen and release volatile oxides. The substance should be in state of powder.

Place the assay near the lower

of the tube and heat gently, Fig. 307, and then strongly, in-
ising the air current by holding the tube more and more nearly
ical.

or that suffocates, bleaching action, .	SO_2,	indicating	**S.**
or of rotten horseradish, ...	SeO_2,	"	**Se.**
or of garlic, ...	As_2O_3,	"	**As.**
limate white volatile octahedral crystals,	As_2O_3,	"	**As.**
limate white partially volatile, fusible to yellow drops, pearl gray cold, .	PbOCl,	"	**$PbCl_2$.**
limate white non-volatile powder, dense fumes, ...	Sb_2O_3,	"	**Sb.**
limate white non-volatile powder, fusible to colorless drops, ...	TeO_2,	"	**Te.**
limate white non-volatile powder, fusible to yellow drops, white when cold,	$PbSO_4$,	"	**PbS.**
limate white non-volatile fusible powder, ...	$BiSO_4$,	"	**BiS.**
limate gray, red at distance, . .	SeO_2,	"	**Se.**
limate yellow hot, white cold, crystalline near the assay, blue in reducing flame, ...	MoO_3,	"	**Mo.**
limate brown hot, yellow cold, fusible,	Bi_2O_3,	"	**Bi.**
limate metallic mirror, . . .		"	**Hg.**

Bead Tests with Borax and with Salt of Phosphorus.

Preliminary to bead tests, many compounds, sulphides, arsenides, enates, etc., may be converted into oxides by roasting as follows: Treat in a shallow cavity on charcoal at a dull red heat, never owing the substance to fuse or even sinter. Use a feeble oxidiz- flame to drive off sulphur, then a feeble reducing flame to luce arsenical compounds, then reheat in an oxidizing flame. rn, crush, and reroast until no sulphurous or garlic odor is ticeable.

Sodium tetraborate or borax may be considered as made up of dium metaborate and boron trioxide. The boron trioxide at a gh temperature combines with metallic oxides, driving out volatile ds, and by the aid, of the oxidizing flame the resulting borates e with the sodium metaborate to form double borates often of characteristic color. The color may differ when hot and cold d according to degree of oxidation and reduction.

Sodium ammonium phosphate, or salt of phosphorus, by fusion loses water and ammonia and becomes sodium metaphosphate. The sodium metaphosphate at high temperatures combines with metallic oxides to form double phosphates and pyrophosphates, which like the double borates are frequently colored, although the colors often differ from those obtained with borax.

A bead of either flux is made on platinum wire as described on page 88, and the substance is added gradually to the warm bead and fused with it in the oxidizing flame. The ease of dissolving, effervescence, color, change of color, etc., should be noted.

We may greatly simplify the tabulation of results by the following division:

1. *Oxides which Color neither Borax or Salt of Phosphorus, or at Most Impart a Pale Yellow to the Hot Bead when Added in Large Amounts.*

Oxides of	Noticeable Distinctions.
Aluminum.	—Cannot be flamed opaque.
Antimony.	—Yellow hot in oxidizing flame, flamed opaque gray in reducing flame, on charcoal with tin black. Expelled by reducing flame in time.
Barium.	—Flamed opaque white.
Bismuth.	—Like antimony.
Cadmium.	—Like antimony, but not made black by fusion with tin.
Calcium.	—Like barium.
Lead.	—Like antimony, but not made black by fusion with tin.
Magnesium.	—Like barium.
Silicon.	—Only partially dissolved in salt of phosphorus.
Strontium.	—Like barium.
Tin.	—Like aluminum.
Zinc.	—Like antimony, but not made black by fusion with tin.

2. *Oxides which Impart Decided Colors to the Beads.*

The colors in hot and cold beads of both fluxes and under both oxidation and reduction are shown in the following table. The abbreviations are: sat = saturated; fl = flamed; op = opaque.

t and cold relate to same bead; *hot* and *cold* to larger amounts the oxide.

Oxides of		Violet.	Blue	Green.	Red.	Brown.	Yellow.	Col'l'ss
Chromium,	O.F.			cold	*hot*		hot	
	R.F.			hot, cold				
Cobalt,	O.F.		hot, cold					
	R.F.		hot, cold					
Copper,	O.F.		cold	hot				
	R.F.				*cold* (op.)	cold		hot
Iron,	O.F.				*hot*		*hot, cold*	cold
	R.F.			hot, cold				
Manganese,	O.F.	hot cold						
	R.F.					*cold*		hot, cold
Molybdenum,	O.F				hot (sat.)		hot	cold
	R.F.					hot, cold		
Nickel,	O.F.	hot				cold		
	R.F.							hot, cold
Titanium,	O.F.						*hot*	hot, cold
	R.F.		flamed			*hot, cold*	hot, cold	
Tungsten,	O.F.						*hot,* (sat.)	hot, cold
	R.F.					cold	hot	cold
Uranium,	O.F.				hot		hot, cold (fl.)	
	R.F.			hot, cold				
Vanadium,	O.F.						*hot, cold*	hot, cold
	R.F.			cold		hot		

Oxides of		Violet.	Blue.	Green.	Red.	Brown.	Yellow.	Col'l'ss
Chromium,	O.F.			cold	hot			
	R.F.			cold	hot			
Cobalt,	O.F.		hot, cold					
	R.F.		hot, cold					
Copper,	O.F.		cold	hot				
	R.F.		hot		cold (op.)			
Iron,	O.F.				*hot*	cold	hot, *cold*	cold
	R.F.				*hot, cold*	cold	hot	cold
Manganese,	O.F.	hot, cold						
	R.F.							hot, cold
Molybdenum,	O.F.			hot				cold
	R.F.			hot, cold				
Nickel,	O.F.				hot		cold	
	R.F.				hot		cold	
Titanium,	O.F.						*hot*	hot, cold
	R.F.	cold					hot	
Tungsten,	O.F.						hot (sat.)	hot, cold
	R.F.		cold	hot				
Uranium,	O.F.			cold			hot	
	R.F.			hot, cold				
Vanadium,	O.F.						hot, cold	
	R.F.			cold		hot		

FLAMING.

Some substances yield a clear glass with borax or salt of phosphorus, which remains clear when cold, but at a certain point near saturation if heated slowly and gently or with an intermittent flame, or unequally, or by alternate oxidizing flame and reducing flame, the bead becomes opaque and enamel-like.

The reason is an incomplete fusion by which a part of the base is separated in the crystalline form.

Flaming is hindered or quite prevented by silica. The borax beads may in general be said to be colored more intensely by equal amounts of coloring oxides, than the salt of phosphorus beads while the latter may be said to yield the greater variety in color.

USE OF TIN WITH BEADS.

Reduction is sometimes assisted by transferring the borax or salt of phosphorus bead to charcoal and fusing it for a moment with a grain or two of metallic tin. The tin oxidizes and takes its oxygen partly from the oxides in the bead.

USE OF LEAD AND GOLD WITH BEADS.

Minute amounts of reduced metals, such as Cu, Ni, Co, may be collected from a bead by fusing it on charcoal with a small button of lead or gold. The glass bead can then be examined for the non-reducible oxides, and the lead or gold can by oxidation in contact with borax or salt of phosphorus, be made again to yield oxide colors from the reduced metals.

Separate the button and the slag, saving both, and heat the button with boracic acid to remove the lead, and then with frequently changed S. Ph. The metals which have united with the gold or lead will be successively oxidized, and their oxides will color the S. Ph. in the following order :

Co.—Blue, hot; blue, cold. May stay in the slag.

Ni.—Brown, hot; yellow, cold. May give green with Co or Cu.

Cu.—Green, hot; blue, cold. Made opaque red by tin and reducing flame.

The slag should contain the more easily oxidizable metals, and be free from Cu, Ni and Ag.

REDUCTION COLOR TESTS.

Saturate two S. Ph. beads with the substance in the oxidizing flame, treat one of them on charcoal with tin and strong reducing flame, pulverize and dissolve separately in cold dilute (1–4)

ydrochloric acid with the addition of a little tin. Let the solu-ons stand for some time and then heat them to boiling.

	The Oxidized Bead Yields		The Reduced Bead Yields	
	In Cold Solution.	In Hot Solution.	In Cold Solution.	In Hot Solution.
.	Blue.	Deep Blue.	Deep Blue.	Deep Blue.
o.	Green to Blue.	Wine Brown.	Brown.	Faint Brown with Black Precipitate.
.	Faint Violet.	Violet and Turbid.	Violet and Turbid.	Violet.
.	Bluish Green.	Green.	Green.	Green.
r.	Green.	Green.	Green.	Green.
r.	Green.	Green.	Green.	Green.

Tests with Sodium Thiosulphate. $Na_2S_2O_3$.

A powdered metallic compound mixed with the dry flux, and ther heated in a closed tube or upon a borax bead inside the ue flame will show the same color as would be produced by ssing H_2S through a solution of the compound.

White = Zn. Orange = Sb. Yellow = Cd, As.
Brown = Sn, Mo. Green = Cr, Mn.
Black = Pb, Fe, Co, Cu, Ni, Ur, Bi, Ag, Au, Pt, Hg.

Use of Acids.

Acids are chiefly used in blowpipe work to expel and detect olatile constituents, to determine ease of solubility or to assist me tests.

Volatile constituents are released with bubbling (effervescence), d the constituent is detected by the odor, or sometimes by ssing the gas into another reagent. Generally a colorless odor-s gas shows the mineral to be a carbonate.

The mineral substance to be treated should be ground to fine wder, unless otherwise stated. Hydrochloric acid is commonly ed but nitric acid is often needed for metallic minerals.

Solubility may be:

With effervescence in the cold.
With effervescence only on heating.
Quiet and easy.
Difficult and incomplete.
With separation of perfect jelly.

With separation of imperfect jelly.
With separation of powder.
With separation of crystals.

Tests with Cobalt Solution.

Cobalt nitrate dissolved in ten parts of water is used to moisten light colored infusible substances. These are then heated to redness in the oxidizing flame and colored compounds result.

BLUE, Al_2O_3 and minerals containing it. Silicates of zinc.
GREEN (bluish) SnO_2.
GREEN (yellowish), ZnO, TiO_2.
GREEN (dark), oxides of antimony and columbium.
FLESH COLOR, MgO, and minerals containing it.

Test with Magnesium Ribbon.

Build a little pyramid of the powdered substance on charcoal, around a half inch length of magnesium ribbon and ignite the ribbon by touching with the flame; after the flash place in water.

Odor of PH_3 = P.

Tests with Acid Potassium Sulphate.

This reagent may be used to decompose insoluble compounds preparatory to wet separation, but its use in blowpipe analysis is chiefly to release volatile vapors and as a component of bismuth flux and boracic acid flux.

COLOR OF FUMES.	ODOR.	REMARKS.	INDICATING.
Brown.	Pungent.	From nitrates.	NO_2.
Brown.	Choking.	Turn starch paper yellow.	Br.
Violet.	Choking.	Turn starch paper violet.	I.
Yellowish-green.	Chlorine.	Explosive.	ClO_2.
Colorless.	Burning sulphur.	———	SO_2.
Colorless.	Pungent.	Corrodes the glass.	HF.
Colorless.	Chlorine.	White vapors with NH_3.	HCl.
Colorless.	Bad eggs.	Blacken lead acetate paper.	H_2S.
Colorless.	Almonds.	Whitens lime water.	HCN.
Colorless.	Odorless.	Whitens lime water.	CO_2.

Others of minor importance, acetic acid, chromic acid, organic ds, etc.

Tests with Potassium Chlorate.

Heat gradually in a matrass with the chlorate; finally there will an energetic oxidation, and the fused mass will be:
Black = Ni, Cu. Bluish black = Co.
Purple = Mn. Brown = Pb. Flesh color = Fe.

Tests with Boracic Acid Flux.

Grind 4½ parts $KHSO_4$, 1 part CaF_2 to paste with water, add bstance, thoroughly mixing. Heat at tip of the blue flame. Just er the water is driven off there may be yellow green flame of ron, or carmine flame of lithia.

Use of Boracic Acid.

Is used to separate lead and bismuth from antimony, copper, dmium, silver, etc.

CHAPTER XIII.

SUMMARY OF USEFUL TESTS WITH THE BLOWPIPE.

THE details of ordinary manipulations, such as obtaining beads, flames, coatings and sublimates, are omitted and the results alone stated; unusual manipulations are described. The bead tests are supposed to be obtained with oxides; the other tests are true, in general, of all compounds not expressly excluded. The course to be followed in the case of interfering elements is briefly stated.

ALUMINUM, Al.

With Soda.—Swells and forms an infusible compound.

With Borax or S. Ph.—Clear or cloudy, never opaque.

*With Cobalt Solution.**—Fine blue when cold.

AMMONIUM, NH_4.

In Closed Tube.—Evolution of gas with the characteristic odor. Soda or lime assists the reaction. The gas turns red litmus paper blue and forms white clouds with HCl vapor.

ANTIMONY, Sb.

On Coal, R. F.†—Volatile white coat, bluish in thin layers, continues to form after cessation of blast and appears to come directly off the mass.

With Bismuth Flux:

On Plaster.—Peach-red coat, somewhat mottled.

On Coal.—Faint yellow or red coat.

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* Certain phosphates, borates and fusible silicates become blue in absence of alumina.

† This coat may be further tested by S. Ph. or flame.

Open Tube.—Dense, white, non-volatile, amorphous sublimate. sulphide, too rapidly heated, will yield spots of red.
Closed Tube.—The oxide will yield a white fusible sublimate edle crystals, the sulphide, a black sublimate red when cold.
ame.—Pale yellow-green.
ith S. Ph.—Dissolved by O. F. and fused on coal with tin in . becomes gray to black.

INTERFERING ELEMENTS.

senic.—Remove by gentle O. F. on coal.
senic with Sulphur.—Remove by gentle heating in closed

pper.—The S. Ph. bead with tin in R. F. may be momentarily ut will blacken.
ead or Bismuth.—Retard formation of their coats by inter- nt blast, or by adding boracic acid. Confirm coat by flame, y S. Ph.

ARSENIC, As.

n Smoked Plaster.—White coat of octahedral crystals.
n Coal.—Very volatile white coat and strong garlic odor. oxide and sulphide should be mixed with soda.
ith Bismuth Flux:
On Plaster.—Reddish orange coat.
On Coal.—Faint yellow coat.
Open Tube.—White sublimate of octahedral crystals. Too heat may form deposit of red or yellow sulphide.
Closed Tube.—May obtain white oxide, yellow or red sul- e, or black mirror of metal. If the tube is broken and the or heated, a strong garlic odor will be noticed.
lame.—Pale azure blue.

INTERFERING ELEMENTS.

ntimony.—Heat in closed tube with soda and charcoal, break treat resulting mirror in O. F. for odor.
obalt or Nickel.—Fuse in O. F. with lead and recognize by .
ulphur.—(*a*) Red to yellow sublimate of sulphide of arsenic in closed tube.
(*b*) Odor when fused with soda on charcoal.

BARIUM, Ba.

On Coal with Soda.—Fuses and sinks into the coal.

Flame.—Yellowish green improved by moistening with HCl.

With Borax or S. Ph.—Clear and colorless, can be flamed opaque-white.

BISMUTH, Bi.

On Coal.—In either flame is reduced to brittle metal and yields a volatile coat, dark orange yellow hot, lemon yellow cold, with yellowish-white border.

*With Bismuth Flux:**

On Plaster.—Bright scarlet coat surrounded by chocolate brown, with sometimes a reddish border. The brown may be made red by ammonia.†

On Coal.—Bright red coat with sometimes an inner fringe of yellow.

With S. Ph.—Dissolved by O. F. and treated on coal with tin in R. F. is colorless hot but blackish gray and opaque cold.

Interfering Elements.

Antimony.—Treat on coal with boracic acid, and treat the resulting slag on plaster with bismuth flux.

Lead.—Dissolve coat in S. Ph. as above.

BORON, B.

All borates intumesce and fuse to a bead.

Flame.—Yellowish green. May be assisted by: (*a*) Moistening with H_2SO_4; (*b*) Mixing to paste with water, and boracic acid flux ($4\frac{1}{2}$ pts. $KHSO_4$, 1 pt. CaF_2); (*c*) By mixing to paste with H_2SO_4 and NH_4F.

BROMINE, Br.

With S. Ph. Saturated With CuO.—Treated at tip of blue flame, the bead will be surrounded by green and blue flames.

In Matrass With $KHSO_4$.—Brown choking vapor.

Interfering Elements.

Silver.—The bromide melts in $KHSO_4$ and forms a blood-red globule which cools yellow and becomes green in the sunlight.

* Sulphur 2 parts, potassic iodide 1 part, potassic bisulphate 1 part.

† May be obtained by heating S. Ph. on the assay.

CADMIUM, Cd.

On Coal R. F.—Dark brown coat, greenish yellow in thin layers. ond the coat, at first part of operation, the coal shows a varie- ed tarnish.

On Smoked Plaster with Bismuth Flux.—White coat made orange $(NH_4)_2S$.

With Borax or S. Ph.—O. F. clear yellow hot, colorless cold, can be flamed milk-white. The hot bead touched to S_2O_3 becomes yellow.

R. F. Becomes slowly colorless.

Interfering Elements.

Lead, Bismuth, Zinc.—Collect the coat, mix with charcoal dust heat gently in a closed tube. Cadmium will yield either a dish brown ring or a metallic mirror. Before collecting coat t it with O. F. to remove arsenic.

CALCIUM, Ca.

On Coal with Soda.—Insoluble and not absorbed by the coal.

Flame.—Yellowish red improved by moistening with HCl.

With Borax or S. Ph.—Clear and colorless, can be flamed opaque.

CARBON DIOXIDE, CO_2.

With Nitric Acid.—Heat with water and then with dilute acid. , will be set free with effervescence. The escaping gas will der lime-water turbid.

With Borax or S. Ph.—After the flux has been fused to a clear d, the addition of a carbonate will cause effervescence during ther fusion.

CHLORINE, Cl.

With S. Ph. Saturated with CuO.—Treated at tip of blue flame, bead will be surrounded by an intense azure-blue flame.

On Coal with CuO.—Grind with a drop of H_2SO_4, spread the ste on coal, dry gently in O. F. and treat with blue flame, which l be colored greenish-blue and then azure-blue.

CHROMIUM, Cr.

With Borax or S. Ph.—O. F. Reddish hot, fine yellow-green cold.

R. F. In borax, green hot and cold. In S. Ph. red hot, green cold.

With Soda.—O. F. Dark yellow hot, opaque and light yellow cold.

R. F. Opaque and yellowish-green cold.

INTERFERING ELEMENTS.

Manganese.—The soda bead in O. F. will be bright yellowish-green.

COBALT, Co.

On Coal, R. F.—The oxide becomes magnetic metal. The solution in HCl will be rose-red but on evaporation will be blue.

With Borax or S. Ph.—Pure blue in either flame.

INTERFERING ELEMENTS.

Arsenic.—Roast and scorify with successive additions of borax. There may be, in order given: Yellow (iron), green (iron and cobalt), blue (cobalt), reddish-brown (nickel), green (nickel and copper), blue (copper).

Copper, and other Elements which Color Strongly.—Fuse with borax and lead on coal in R. F. The borax on platinum wire in O. F. will show the cobalt, except when obscured by much iron or chromium.

Iron, Nickel or Chromium.—Fuse in R. F. with a little metallic arsenic, then treat as an arsenide.

Sulphur or Selenium.—Roast and scorify with borax, as before described.

COPPER, Cu.

On Coal R. F.—Formation of red malleable metal.

*Flame.**—Emerald-green or azure-blue, according to compound. The azure-blue flame may be obtained:

(*a*) By moistening with HCl or aqua regia, drying gently in O. F. and heating strongly in R. F.

(*b*) By saturating S. Ph. bead with substance, adding common salt, and treating with blue flame.

With Borax† or S. Ph.—O. F. Green hot, blue or greenish-blue cold.

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* Sulphur, selenium and arsenic should be removed by roasting. Lead necessitates a gentle heat.

† By repeated slow oxidation and reduction, a borax bead becomes ruby red.

R. F. Greenish or colorless hot, opaque and brownish-red cold. With tin on coal this reaction is more delicate.

INTERFERING ELEMENTS.

*General Method.**—Roast thoroughly, treat with borax on coal strong R. F., and

If Button Forms.—Separate the button from the slag, remove any lead from it by O. F., and make either S. Ph. or flame test upon residual button.

If no Visible Button Forms.—Add test lead to the borax fusion, continue the reduction, separate the button and treat as in next test. (Lead Alloy.)

Lead or Bismuth Alloys.—Treat with frequently changed boracic d in strong R. F., noting the appearance of slag and residual ton.

Trace.—A red spot in the slag.

Over One Per Cent.—The residual button will be bluish-green when melted, will dissolve in the slag and color it red upon application of the O. F., or may be removed from the slag and be submitted to either the S. Ph. or the flame test.

FLUORINE, F.

Etching Test.—If fluorine is released it will corrode glass in udy patches, and in presence of silica there will be a deposit the glass. According to the refractoriness of the compound fluorine may be released:

a) In closed tube by heat.

b) In closed tube by heat and $KHSO_4$

c) In open tube by heat and glass of S. Ph.

With Conc. H_2SO_4 and SiO_2.—If heated and the fumes condensed a drop of water upon a platinum wire, a film of silicic acid will m upon the water.

IODINE, I.

With S. Ph. Saturated with CuO.—Treated at the tip of the blue me the bead is surrounded by an intense emerald-green flame.

In Matrass with $KHSO_4$.—Violet choking vapor and brown blimate.

* Oxides, sulphides, sulphates are best reduced by a mixture of soda and borax.

In Open Tube with Equal Parts Bismuth Oxide, Sulphur and Soda.—A brick-red sublimate.

With Starch Paper.—The vapor turns the paper dark purple.

INTERFERING ELEMENTS.

Silver.—The iodide melts in $KHSO_4$ to a dark red globule, yellow on cooling, and unchanged by sunlight.

IRON, Fe.

On Coal.—R. F. Many compounds become magnetic. Soda assists the reaction.

*With Borax.**—O. F. Yellow to red hot, colorless to yellow cold.

R. F. Bottle-green. With tin on coal, vitriol-green.

With S. Ph.—O. F. Yellow to red hot, greenish while cooling, colorless to yellow cold.

R. F. Red hot and cold, greenish while cooling.

State of the Iron.—A borax bead blue from CuO is made red by FeO, and greenish by Fe_2O_3.

INTERFERING ELEMENTS.

Chromium.—Fuse with nitrate and carbonate of soda on platinum, dissolve in water and test residue for iron.

Cobalt.—By dilution the blue of cobalt in borax may often be lost before the yellow of iron.

Copper.—May be removed from borax bead by fusion with lead on coal in R. F.

Manganese.—(*a*) May be faded from borax bead by treatment with tin on coal in R. F.

(*b*) May be faded from S. Ph. bead by R. F.

Nickel.—May be faded from borax bead by R. F.

Tungsten or Titanium.—The S. Ph. bead in R. F. will be reddish-brown instead of blue or violet.

Uranium.—As with chromium.

Alloys, Sulphides, Arsenides, etc.—Roast, treat with borax on coal in R. F., then treat borax in R. F. to remove reducible metals.

LEAD, Pb.

On Coal.†—In either flame is reduced to malleable metal and

* A slight yellow color can only be attributed to iron, when there is no decided color produced by either flame in highly charged beads of borax and S. Ph.

† The phosphate yields no coat without the aid of a flux.

lds, near the assay, a dark lemon-yellow coat, sulphur-yellow d and bluish-white at border.

With Bismuth Flux:

On Plaster.—Chrome-yellow coat, blackened by $(NH_4)_2S$.

On Coal.—Volatile yellow coat, darker hot.

Flame.—Azure-blue.

With Borax or S. Ph.—O. F. Yellow hot, colorless cold, flames opaque-yellow.

R. F. Borax bead becomes clear, S. Ph. bead cloudy.

INTERFERING ELEMENTS.

Antimony.—Treat on coal with boracic acid, and treat the re-ting slag on plaster with bismuth flux.

Arsenic Sulphide.—Remove by gentle O. F.

Cadmium.—Remove by R. F.

Bismuth.—Usually the bismuth flux tests on plaster are sufficient. addition the lead coat should color the R. F. blue.

LITHIUM, Li.

Flame,—Crimson, best obtained by gently heating near the wick.

INTERFERING ELEMENTS.

Sodium, (*a*) Use a gentle flame and heat near the wick. (*b*) Fuse platinum wire with barium chloride in O. F. The flame will be st strong yellow, then green, and lastly, crimson.

Calcium or Strontium.—As these elements do not color the flame the presence of barium chloride, the above test will answer.

Silicon.—Make into a paste with boracic acid flux and water, and e in the blue flame. Just after the flux fuses the red flame will pear.

MAGNESIUM, Mg.

On Coal with Soda.—Insoluble, and not absorbed by the coal.

With Borax or S. Ph.—Clear and colorless can be flamed opaque-ite.

*With Cobalt Solution.**—Strongly heated becomes a pale flesh lor.

MANGANESE, Mn.

With Borax or S. Ph.†—O. F. Amethystine hot, reddens on cool-

* With silicates this reaction is of use only in the absence of coloring oxides. The osphate, arsenate and borate become violet-red.

† The colors are more intense with borax than with S. Ph.

ing. With much, is black and opaque. If a hot bead is touched to a crystal of sodium nitrate an amethystine or rose-colored froth is formed.

R. F. Colorless or with black spots.

With Soda.—O. F. Bluish-green and opaque when cold. Sodium nitrate assists the reaction.

INTERFERING ELEMENTS.

Chromium.—The soda bead in O. F. will be bright yellowish-green instead of bluish-green.

Silicon.—Dissolve in borax, then make soda fusion.

MERCURY, Hg.

With Bismuth Flux:

On Plaster.—Volatile yellow and scarlet coat. If too strongly heated the coat is black and yellow.

On Coal.—Faint yellow coat at a distance.

*In Matrass with Dry Soda or with Litharge.**—Mirror-like sublimate, which may be collected in globules.

MOLYBDENUM, Mo.

On Coal.—O. F. A coat yellowish hot, white cold, crystalline near assay.

R. F. The coat is turned in part deep blue, in part dark copper-red.

Flame.—Yellowish-green.

With Borax.—O. F. Yellow hot, colorless cold.

R. F. Brown to black and opaque.

With S. Ph.—O. F. Yellowish-green hot, colorless cold.†

R. F. Emerald-green.

Dilute (¼) HCl Solutions.—If insoluble the substance may first be fused with S. Ph. in O. F. If then dissolved in the acid and heated with metallic tin, zinc or copper, the solutions will be successively blue, green and brown. If the S. Ph. bead has been treated in R. F. the solution will become brown.

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* Gold-leaf is whitened by the slightest trace of vapor of mercury.

† Crushed between damp unglazed paper becomes red, brown, purple or blue, according to amount present.

NICKEL, Ni.

On Coal.—R. F. The oxide becomes magnetic.

With Borax.—O. F. Violet hot, pale reddish-brown cold.

R. F. Cloudy and finally clear and colorless.

With S. Ph.—O. F. Red hot, yellow cold.

R. F. Red hot, yellow cold. On coal with tin becomes colorless.

INTERFERING ELEMENTS.

General Method.—Saturate two or three borax beads with roasted stance, and treat on coal with a strong R. F. If a visible button lts, separate it from the borax, and treat with S. Ph. in the F., replacing the S. Ph. when a color is obtained.

no visible button results, add either a small gold button or a grains of test lead. Continue the reduction, and :

With Gold.—Treat the gold alloy on coal with S. Ph. in strong O. F.

With Lead.—Scorify button with boracic acid to small size, complete the removal of lead by O. F. on coal, and treat residual button with S. Ph. in O. F.

Arsenic.—Roast thoroughly, treat with borax in R. F. as long as ows color, treat residual button with S. Ph. in O. F.

Alloys.—Roast and melt with frequently changed borax in R. F. ing a little lead if infusible. When the borax is no longer ored, treat residual button with S. Ph. in O. F.

NITRIC ACID, HNO_3.

In Matrass with $KHSO_4$, or in Closed Tube with Litharge.—Brown es with characteristic odor. The fumes will turn ferrous sul- te paper brown.

PHOSPHORUS, P.

Flame.—Greenish-blue, momentary. Improved by conc. H_2SO_4.

In Closed Tube with Dry Soda and Magnesium.—The soda and stance are mixed in equal parts and dried, and made to cover magnesium. Upon strongly heating there will be a vivid in- descence, and the resulting mass, crushed and moistened, will d the odor of phosphuretted hydrogen.

POTASSIUM, K.

Flame.—Violet, except borates and phosphates.

INTERFERING ELEMENTS.

Sodium.—(*a*) The flame, through blue glass, will be violet or blue.

(*b*) A bead of borax and a little boracic acid, made brown by nickel, will become blue on addition of a potassium compound.

Lithium.—The flame, through green glass, will be bluish-green.

SELENIUM, Se.

On Coal, R. F.—Disagreeable horse-radish odor, brown fumes, and a volatile steel-gray coat with a red border.

In Open Tube.—Steel-gray sublimate, with red border, sometimes white crystals.

In Closed Tube.—Dark-red sublimate and horse-radish odor.

Flame.—Azure-blue.

On Coal with Soda.—Thoroughly fuse in R. F., place on bright silver, moisten, crush, and let stand. The silver will be blackened.

SILICON, Si.

On Coal with Soda.—With its own volume of soda, dissolves with effervescence to a clear bead. With more soda the bead is opaque.

With Borax.—Clear and colorless.

With S. Ph.—Insoluble. The test made upon a small fragment will usually show a translucent mass of undissolved matter of the shape of the original fragment.

When not decomposed by S. Ph., dissolve in borax nearly to saturation, add S. Ph., and re-heat for a moment. The bead will become milky or opaque white.

SILVER, Ag.

On Coal.—Reduction to malleable white metal.

With Borax or S. Ph.—O. F. Opalescent.

Cupellation.—Fuse on coal with 1 vol. of borax glass and 1 to 2 vols. of test lead in R. F. for about two minutes. Remove button and scorify it in R. F. with fresh borax, then place button on cupel and blow O. F. *across* it, using as strong blast and as little flame as are consistent with keeping button melted.

If the litharge is dark, or if the button freezes before brightening, or if it brightens but is not spherical, rescorify it on coal with borax,

dd more test lead, and again cupel until there remains only a white herical button of silver.

SODIUM, Na.

Flame.—Strong reddish-yellow.

STRONTIUM, Sr.

On Coal with Soda.—Insoluble, absorbed by the coal.

Flame.—Intense crimson, improved by moistening with HCl.

With Borax or S. Ph.—Clear and colorless; can be flamed paque.

Interfering Elements.

Barium.—The red flame may show upon first introduction of ne sample into the flame, but it is afterward turned brownish-ellow.

Lithium.—Fuse with barium chloride, by which the lithium flame unchanged.

SULPHUR, S.

On Coal with Soda and a Little Borax.—Thoroughly fuse in the . F., and either:

(*a*) Place on bright silver, moisten, crush and let stand. The silver will become brown to black. Or,

(*b*) Heat with dilute HCl (sometimes with powdered zinc); the odor of H_2S will be observed.

In Open Tube.—Suffocating fumes. Some sulphates are unaf-cted.

In Closed Tube.—May have sublimate red when hot, yellow cold, r sublimate of undecomposed sulphide, or the substance may be naffected.

With Soda and Silica (equal parts).—A yellow or red bead.

To Determine Whether Sulphide or Sulphate.—Fuse with soda on latinum foil. The sulphide only will stain silver.

TELLURIUM, Te.

On Coal.—Volatile white coat with red or yellow border. If ne fumes are caught on porcelain, the resulting gray or brown im may be turned crimson when moistened with conc. H_2SO_4, nd gently heated.

On Coal with Soda.—Thoroughly fuse in R. F. Place on bright silver, moisten, crush and let stand. The silver will be blackened.

Flame.—Green.

In Open Tube.—Gray sublimate fusible to clear drops.

With H_2SO_4 (conc.).—Boiled a moment, there results a purple violet solution, which loses its color on further heating or on dilution.

TIN, Sn.

On Coal.—O. F. The oxide becomes yellow and luminous.

R. F. A slight coat, assisted by addition of sulphur or soda.

With Cobalt Solution.—Moisten the coal, in front of the assay, with the solution, and blow a *strong* R. F. upon the assay. The coat will be bluish-green when cold.

With CuO in Borax Bead.—A faint blue bead is made reddish-brown or ruby-red by heating a moment in R. F. with a tin compound.

Interfering Elements.

Lead or Bismuth (Alloys).—It is fair proof of tin if such an alloy oxidizes rapidly with sprouting and cannot be kept fused.

Zinc.—On coal with soda, borax and charcoal in R. F. the tin will be reduced, the zinc volatilized; the tin may then be washed from the fused mass.

TITANIUM,* Ti.

With Borax.—O. F. Colorless to yellow hot, colorless cold, opalescent or opaque-white by flaming.

R. F. Yellow to brown, enamel blue by flaming.

With S. Ph.—O. F. As with borax.

R. F. Yellow hot, violet cold.

HCl Solutions.—If insoluble the substance may first be fused with S. Ph. or with soda and reduced. If then dissolved in dilute acid and heated with metallic tin, the solution will become violet after standing. Usually there will also be a turbid violet precipitate, which becomes white.

Interfering Elements.

Iron.—The S. Ph. bead in R. F. is yellow hot, brownish-red cold.

TUNGSTEN, W.

With Borax.—O. F. Colorless to yellow hot, colorless cold, can be flamed opaque-white.

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* If the substance is mixed with sodium fluoride, fused on platinum with a little sodium pyrosulphate and dissolved by boiling in a very weak solution of sulphuric acid, the addition of a few drops of hydrogen peroxide will produce a color like that of ferric chloride.

R. F. Colorless to yellow hot, yellowish-brown cold.

With S. Ph.—O. F. Clear and colorless.

R. F. Greenish hot, blue cold. On long blowing or with tin on coal, becomes dark green.

With Dilute HCl.—If insoluble, the substance may first be fused th S. Ph. The solution heated with tin becomes dark blue; th zinc it becomes purple and then reddish-brown.

INTERFERING ELEMENTS.

Iron.—The S. Ph. in R. F. is yellow hot, blood-red cold.

URANIUM, U.

With Borax.—O. F. Yellow hot, colorless cold, can be flamed enamel yellow.

R. F. Bottle-green, can be flamed black but not enamelled.

With S. Ph.—O. F. Yellow hot, yellowish-green cold.

R. F. emerald-green.

INTERFERING ELEMENTS.

Iron.—With S. Ph. in R. F. is green hot, red cold.

VANADIUM, V.

With Borax.—O. F. Colorless or yellow hot, greenish-yellow

R. F. Brownish hot, emerald-green cold.

With S. Ph.—O. F. Dark yellow hot, light yellow cold.

R. F. Brown hot, emerald-green cold.

H_2SO_4 *Solutions.*—Reduced by Zn become successively yellow, reen, bluish-green, blue, greenish-blue, bluish-violet and lavender.

ZINC, Zn.

On Coal.—O. F. The oxide becomes yellow and luminous.

R. F. Yellow coat, white when cold, assisted by soda and little borax.

With Cobalt Solution.—Moisten the coal, in front of the assay, ith the solution, and blow a strong R. F. upon the assay. The oat will be bright yellow-green when cold.

Interfering Elements.

Antimony.—Remove by strong O. F., or by heating with sulphur in closed tube.

Cadmium, Lead or Bismuth.—The combined coats will not prevent the cobalt solution test.

Tin.—The coats heated in an open tube, with charcoal dust by the O. F., may yield white sublimate of zinc.

CHAPTER XIV.

SCHEMES FOR QUALITATIVE BLOWPIPE ANALYSIS.

Test I.*—Heat a portion gently with O. F. upon charcoal a plaster tablet which has been blackened in the lamp me.

As.—White very volatile crystalline coat, white fumes having rlic odor and invisible near assay, best on plaster.

he coat disappears before R. F., tingeing it pale blue and evolving the characteristic ic odor.

ONFIRMATION **As.**—The coating may be scraped off together with a little charcoal if heated in closed tube should yield an arsenic mirror; or it may be dissolved in tion of KOH, placed in a test tube, a small piece of sodium amalgam added, and tube covered with a piece of filter paper moistened with a *slightly* acid solution of NO_3. The paper will be stained black by the AsH_3 evolved.

Sb.—White fumes and white pulverulent volatile coat, best on rcoal.

good distinguishing feature between As and Sb is as follows: They both usually inue to give off fumes after removal of the flame, but while still hot the As_2O_3 fumes not visible within one-half inch of assay, while Sb_2O_4 fumes appear to come immeely from the mass.

ONFIRMATION **Sb.**—The coating disappears before R. F., tingeing it a pale yellowen, or, if scraped together, dissolved in S. Ph. and *just* fused on charcoal in contact tin it will form a gray or black opaque bead.

f the coating be scraped off and dissolved in tartaric acid + HCl, and the solution ed in a platinum capsule with a piece of zinc, Sb, if present, will give a black erent stain. This may be confirmed by washing the stain with water, then dissolvit in a few drops of hot tartaric acid plus a drop or two of HCl; on adding H_2S, an ge precipitate proves Sb_2S_3.

Most antimony minerals leave a white residue when treated with concentrated nitric . If this residue is washed with water dissolved in HCl and H_2S added, an orange ipitate of Sb_2S_3 will be formed.

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* Test I. may also yield white coating of chlorides or lead sulphate, or of Se or Te, -volatile coatings of Sn or Zn near the assay, yellow hot and white cold; yellow ings of Pb or Bi; crystalline yellow and white coating of Mo; and deep brown ing of Cd. All of these will be detected with greater certainty by later tests.

TEST II.—**Mix a portion with soda and a little borax and heat strongly upon charcoal with R. F. for three or four minutes. Preserve the fused mass for subsequent examination. Or, mix some of the powdered substance with metallic sodium by means of a knife blade, ignite carefully on charcoal and heat residue with blowpipe flame to obtain coatings or to fuse together any metallic particles.* Preserve residue for Test III.**

As.—Garlic odor, white fumes and a white volatile coat.

Sb.—White fumes and a white volatile coat.

Cd.—Dark brown volatile coat, sometimes shading to greenish-yellow and usually surrounded by a variegated coloration resembling the colors of peacock feathers.

CONFIRMATION **Cd.**—The coat forms at first heating, and, if mixed with $Na_2S_2O_3$ and fused in a borax bead, will form a bright yellow mass of CdS.

Zn.—White not easily volatile coat, yellow when hot.

Sn.—White non-volatile coat close to assay, yellow while hot and usually small in amount.

CONFIRMATION **Zn** and **Sn.**—If any coat forms, moisten it with cobalt solution and blow a strong blue flame on the substance. The coatings from other elements will not prevent the cobalt coloration. The zinc coat is made bright yellowish green. The tin coat becomes bluish-green.

TEST III.—**Crush, and pulverize and examine the residue of Test II.**

1. **Collect any magnetic particles with the magnet; dissolve some of the magnetic particles in a borax bead with the O. F. Try also effect of R. F.**

Fe.—The bead is: O. F. hot, yellow to red; O. F. cold, colorless to yellow; R. F. cold, bottle-green.

CONFIRMATION **Fe.**—The magnetic particles yield with HNO_3, a brown solution from which, after evaporating excess of acid, K_4FeCy_6 throws down a blue precipitate.

Ni.—The bead is: O. F. hot, intense violet; O. F. cold, pale brown; R. F. cold, colorless.

CONFIRMATION **Ni.**—If the excess of acid is driven off by evaporation, KCy added in excess, and the solution then made strongly alkaline with KOH, two or three drops of pure bromine will give a black precipitate of $Ni_2(OH)_6$.

Co.—The bead is: O. F. and R. F. hot or cold, a deep pure blue; if greenish when hot, probably Fe or Ni is also present.

CONFIRMATION **Co.**—The magnetic particles yield with HNO_3, a rose-red solution which becomes blue on evaporation.

* Test II. may also yield white coats from Pb, Bi or alkalis, yellow coats from Pb or Bi, brown or red coats from Cu or Mo, and the ash of the coal may be white or red.

2. Examine residue for metallic buttons and observe if they e malleable or not.

Ag.—Silver white malleable button.

CONFIRMATION **Ag.**—Dissolve button in dilute HNO_3, and add a drop of HCl. A ite precipitate, soluble in NH_4OH is obtained.

Pb.—Lead gray malleable button.

CONFIRMATION **Pb.**—With bismuth flux on charcoal gives yellow coating.

Sn.—White malleable button.

CONFIRMATION **Sn.**—Heated in O. F. on charcoal gives a non-volatile coating, yellow and white cold. Decomposed in conc. HNO_3 with white residue of metastannic acid.

Cu.—Reddish malleable button.

CONFIRMATION **Cu.**—Dissolves in HNO_3 to a green solution rendered intense blue en neutralized with NH_4OH.

Au.—Yellow malleable button.

CONFIRMATION **Au.**—Insoluble in HNO_3 or HCl alone, but dissolved by mixed acids.

Bi.—Reddish white brittle button.

CONFIRMATION **Bi.**—Heat with bismuth flux.

Sb.—White brittle button, yielding white coating before the owpipe.

3. Dig up some of the charcoal beneath assay, place upon bright silver surface; moisten with water and let stand.

S, Se, Te.—The bright silver is stained black or dark-brown, d unless the horseradish odor of Se or the brown coatings of and Te with bismuth flux have been already obtained, this stain ll prove sulphur.

CONFIRMATIONS **S.**—The soda fusion will evolve H_2S when moistened with HCl. holding in the gas a piece of filter paper moistened with a drop or two of lead tate (test is made more sensitive by adding a drop of ammonia to the acetate), the per will be stained black.

CONFIRMATION **Se.**—Characteristic disagreeable horseradish odor during fusion.

CONFIRMATIONS **Te.**—If a little of the original substance is dropped into boiling ncentrated H_2SO_4, a deep violet color is produced; this disappears on further ting.

The quite cold soda fusion added to hot water produces a purple-red solution.

TEST IV.—Mix a portion of the substance with more than equal volume of bismuth flux,* and heat gently upon a aster tablet with the oxidizing flame.

* Formed by grinding together 1 part KI, part $KHSO_4$, 2 parts S.

Pb.—Chrome-yellow coat, darker hot, often covering the entire tablet.

CONFIRMATION **Pb.**—If the test is made on charcoal, the coat is greenish-yellow, brown near the assay.

Hg.—Gently heated, bright scarlet coat, very volatile, and with yellow fringe; but if quickly heated, the coat formed is pale yellow and black.

CONFIRMATION **Hg.**—If the substance is heated gently in a closed tube or matrass with dry soda or litharge, a mirror-like sublimate will form, which may be collected into little globules of Hg by rubbing with a match end. The test with bismuth flux on charcoal yields only a faint yellow coat.

Bi.—Bright chocolate-brown coat, with sometimes a reddish fringe.

CONFIRMATIONS **Bi.**—The coat is turned orange-yellow, then cherry-red, by fumes of NH_3, which may conveniently be produced by heating a few crystals of S. Ph. on the assay. The test with bismuth flux on charcoal yields a bright-red band, with sometimes an inner fringe of yellow.

Sb.—Orange to peach-red coat, very dark when hot.

CONFIRMATION **Sb.**—The coat becomes orange when moistened with $(NH_4)_2S$.

Test IV. may yield colored sublimates with large amounts of certain other elements, and on smoked plaster certain white sublimates are obtainable. In all cases the elements are detected with greater certainty by other tests, but for convenience they are here summarized: Sn, brownish-orange; As, reddish-orange; Se, reddish-brown; Te, purplish-brown, with deep brown border; Mo, deep ultramarine blue; Cu, Cd, Zn, white on smoked plaster.

TEST V.—**Dissolve substance in salt of phosphorus in O. F. so long as bead remains clear on cooling. Treat then for three or four minutes in a strong R. F. to remove volatile compounds. Note the colors hot and cold, then re-oxidize and note colors hot and cold.**

Fe, Ti, Mo, W.—The bead in O. F. cold is COLORLESS or very FAINT YELLOW.

CONFIRMATION **Fe.**—The bead in its previous treatment should have been O. F. hot, yellow to red; O. F. cold, colorless; R. F. cold, bottle green.

CONFIRMATION **Ti.**—The bead is reduced on charcoal with tin, pulverized and dissolved in $\frac{1}{4}$ HCl with a little metallic tin. The reduced bead is violet, the solution is violet and turbid.

CONFIRMATIONS **Mo.**—Tested as above on charcoal with tin, etc., the reduced bead is green, the solution is dark brown. Heat a little of the substance on platinum foil with a few drops of conc. HNO_3, heat until excess of HNO_3 has all volatilized, then add

ops of strong H_2SO_4 and heat until copious fumes are evolved; cool, and breathe n the cooled mass; an ultramarine blue = Mo.

CONFIRMATION **W.**—Tested on charcoal with tin, etc., as above, the reduced bead reen, the solution is deep blue.

Ur, V, Ni.*—The bead in O. F. cold, is colored YELLOW OR EENISH-YELLOW.

CONFIRMATION **U.**—The bead in R. F. is dull green, hot; fine green, cold. Make a_2CO_3 fusion, dissolve in HCl or H_2SO_4, add a few drops or H_2S water, and if it s any precipitate, add it in excess and filter; to filtrate add a few drops of HNO_3 boil, then add NH_4OH to alkaline reaction, filter, wash precipitate with ammonia er, and then treat precipitate with a concentrated solution of $(NH_4)_2CO_3 + NH_4OH$, r, acidify filtrate with HCl, and add K_4FeCy_6. Brown ppt. = Ur.

CONFIRMATION **V.**—In R. F. the bead will be brownish hot, fine green cold. Fuse stance with Na_2CO_3 in O. F., and dissolve fusion in a few drops of dilute H_2SO_4 HCl, add a piece of zinc and warm; blue color changing to green and finally vio- = V.

CONFIRMATION **Ni.**—A borax bead in O. F. will be intense violet, and in R. F. will eddish hot, yellow cold.

Mn.—The bead in O. F., cold, is colored VIOLET; if touched ile hot to a crystal of nitre, it is made deep permanganate color.

CONFIRMATION **Mn.**—Fused on platinum wire in O. F., with a paste of soda, and e, manganese yields an opaque bluish-green bead.

Cr.—The bead in O. F., cold, is colored GREEN.

If the absence of Ni is not proved, or Co obscures the tests, dissolve the substance orax on charcoal to saturation, and treat for five minutes in hot R. F.

a visible button results, separate it from the borax, and treat with S. Ph. in the ., replacing the S. Ph. when a color is obtained.

no visible button results, add either a small gold button or a few grains of test . Continue the reduction, and, if lead has been used, scorify the button with fre- ntly changed boracic acid to small size, stopping the instant the boracic acid is red by Co, Ni, or Cu, blue, yellow, or red, respectively.

omplete the removal of lead by O. F. on coal, and treat as below.

reat the gold alloy, or the residual button from the lead alloy, on coal, with fre- ntly changed S. Ph., in strong O. F.

The metals which have united with the gold or lead, will be successively oxidized their oxides will color the S. Ph. in the following order:

o.—Blue, hot; blue, cold. May stay in the slag.

Ni.—Brown, hot; yellow, cold. May give green with Co or Cu.

Cu.—Green, hot; blue, cold. Made opaque red by tin and R. F.

The slag should contain the more easily oxidizable metals, and be free from Cu, and Ag. Test a portion with S. Ph. and tin to prove absence of Cu. If present, it t be removed by further reduction with lead. Pulverize the slags and dissolve a ion in S. Ph., and examine by Test V.

There may be a green bead from admixture of a blue and a yellow. If Cr is not proved, examine in such a case for Ur, V, Cr, etc., with unusual care.

CONFIRMATION **Cr.**—If the substance is fused on platinum wire in the O.F. with a paste of soda and nitre, an opaque yellow bead is produced; and if the soda bead is dissolved in water, filtered, acidified with acetic acid, and a drop or two of lead acetate added, a yellow precipitate will be formed.

Co, Cu.—The bead in O. F., cold, is colored BLUE.

CONFIRMATION **Co.**—The bead is deep blue, hot and cold, in both flames.

CONFIRMATION **Cu.**—The bead is green, hot, greenish-blue, cold, and on fusion with tin on coal becomes opaque brownish-red.

With larger percentage of copper, the substance will yield a mixed azure-blue and green flame on heating with HCl.

SiO_2, Al_2O_3, TiO_2, SnO_2.—The saturated bead contains an appreciable amount of INSOLUBLE MATERIAL, in the form of a *translucent* cloud, jelly-like mass, or skeleton form of the original material.

CONFIRMATION **SiO_2.**—Mix the *dry* substance with a little *dry* calcium fluoride free from SiO_2, place in a *dry* test tube and add conc. H_2SO_4 and heat gently, hold in fumes given off, a drop of water in loop of platinum wire; SiO_2 will be separated on coming in contact with the water and form a jelly-like mass.

Silica or silicates fused with soda unite with noticeable effervescence.

CONFIRMATION **Al_2O_3, TiO_2, SnO_2, SiO_2.**—If infusible, moisten the pulverized mineral with dilute cobalt nitrate solution and heat strongly.

Al_2O_3.—Beautiful bright blue.

TiO_2.—Yellowish green.

SnO_2.—Bluish green.

SiO_2.—Faint blue; deep blue, if fusible.

There may also be blues from fusible phosphates and borates, greens from oxides of Zn, Sb, violet from Zr, various indefinite browns and grays, and a very characteristic pale pink or flesh color from Mg.

CONFIRMATION **SnO_2.**—Treat the finely pulverized mineral with Zn and HCl in contact with platinum. Dissolve any reduced metal in HCl and test with $HgCl_2$. There will be white or gray ppt.

Ba, Ca, Sr, Mg.—The saturated bead is WHITE and OPAQUE and the nearly saturated bead can be flamed white and opaque.

CONFIRMATION **Ba, Ca, Sr.**—Moisten the flattened end of a clean platinum wire with dilute hydrochloric acid, dip it in the roasted substance, and heat strongly at the tip of the blue flame, and gently near the wick. Remoisten with the acid frequently.

Ba.—Yellowish-green flame, bluish-green through green glass.

Ca.—Yellowish-red (brick-red) flame, green through green glass.

Sr.—Scarlet-red flame, faint yellow through green glass.

There may also be produced **Li**, carmine-red flame, invisible through green glass.

, rose-violet flame, reddish-violet through blue glass. **Na**, orange-yellow flame, visible through blue glass. **Cu**. azure-blue and emerald green. **Se** and **As**, pale ue. **Mo, Sb, Te**, pale green.

CONFIRMATION **Mg**.—Moisten the roasted substance with cobalt solution, and heat rongly. The substance will be colored pale pink or flesh color, or violet if present either arsenate or phosphate.

TEST VI.—Cupellation for silver and gold. Fuse one vol. f the roasted substance on charcoal with 1 vol. of borax glass, nd 1 to 2 vols. of test lead in R. F. for about two minutes. emove button and scorify it in R. F. with fresh borax, then lace button on cupel and blow O. F. *across* it, using as strong last and as little flame as are consistent with keeping the utton melted. If the litharge is dark, or if the button freezes efore brightening, or if it brightens but is not spherical, re-corify it on charcoal with borax, add more test lead, and gain cupel until there remains only a bright spherical button naltered by further blowing.

Ag.—The button is white.
Au.—The button is yellow or white.

CONFIRMATION **Ag** AND **Au.**—Dissolve in a drop of HNO_3, and add a drop of Cl, producing a white curd-like precipitate. If gold is present there will be a resi-ue insoluble in HNO_3 which will become golden yellow on ignition.

TEST VII.—Heat substance in matrass with acid potassium ulphate.

N_2O_5, Br.—Reddish brown vapor.

CONFIRMATION **N_2O_5**.—The gas turns ferrous sulphate paper brown. Nitrates defla-rate violently when fused on charcoal.

Cl.—Colorless or yellowish green vapor, with odor of chlorine.
I.—Violet choking vapor.

CONFIRMATION **Br, Cl, I.**—Saturate a salt of phosphorus bead with CuO, add sub-ance, and treat in O. F. Br, azure blue and emerald green flame. Cl, azure blue ame with a little green. I, emerald green flame.

Fuse with Na_2CO_3, pulverize and mix with MnO_2, and add a few drops of conc. $_2SO_4$, and heat. Cl, yellowish green gas that bleaches vegetable colors. Br, red mes.

Fuse with Na_2CO_3, dissolve in water, make slightly acid with H_2SO_4, and add $_2(SO_4)_3$ (ferric alum may be used), and boil; I, violet fumes (turn starch paper ue).

F.—The glass of the matrass is corroded, and if SiO_2 is present a film of SiO_2 is often deposited on the glass.

CONFIRMATION **F.**—If the substance be mixed with silica and then heated with concentrated sulphuric acid, and the fumes caught on a drop of water held in a loop of platinum wire, gelatinous silica will form in the water.

TEST VIII.—Heat the substance gently with water to remove air bubbles and then with dilute hydrochloric acid.

CO_2.—Effervescence continuing after heat is removed.

H_2S, Cl and H are sometimes evolved, but usually the odor will distinguish these.

CONFIRMATION **CO_2.**—If the gas is passed into lime water, a white cloud and ppt. will be produced.

TEST IX.—Place a piece of Mg wire in a closed tube, and cover the wire with a mixture of soda and the substance. Heat till the mass takes fire, cool and add water.

P.—Evolution of phosphine, recognized by odor.

CONFIRMATION **P.**—Fuse a little of the substance, previously roasted if it contains As, with two or three parts Na_2CO_3 and one of $NaNO_3$ dissolve in HNO_3, and add excess of $(NH_4)_2MoO_4$; yellow ppt. $= P_2O_5$. In presence of SiO_2 it is well to confirm this ppt. by dissolving it in dilute NH_4OH, allowing it to stand for half an hour and filtering off any SiO_2 that separates, then to filtrate adding magnesia mixture ($MgCl_2 + NH_4Cl + NH_4OH$); white ppt. $= P_2O_5$.

Phosphates yield a pale momentary bluish green flame when moistened with concentrated H_2SO_4 and treated at the tip of the blue flame.

TEST X.—Make a paste of four parts $KHSO_4$, one part CaF_2, water and substance. Treat at tip of blue flame. Just after water is driven off the flame will be colored.

B.—Bright green.

Li.—Carmine.

CONFIRMATION **B.**—Heat some of the substance gently on platinum wire, then add a drop of concentrated H_2SO_4, heat very gently again, just enough to drive off excess of H_2SO_4, dip in glycerine, hold in flame until glycerine begins to burn, remove from flame, and the mass will continue burning with a green flame. Turmeric paper, moistened with an HCl solution containing boron and dried at 100°, is turned a reddish brown which ammonia blackens.

TEST XI.—Make a paste of the powdered substance with strong HCl. Treat on platinum wire in the non-luminous flame of a Bunsen burner. Confirm results by the spectroscope as directed on page 93.

The color imparted to the flame is:

	Alone.	*Through blue glass.*
Na,	Yellow.	Invisible or pale blue.
K,	Violet.	Reddish violet.
Na and K,	Yellow.	Reddish violet.
Ba, Mo, B,	Yellowish green.	Bluish green.
Ca,	Red.	Greenish grey.
Sr,	Scarlet.	Violet.
Cu,	Azure blue, Emerald green.	Azure blue, Emerald green.

TEST XII.—**Heat the substance in a closed tube.***

H_2O.—Moisture on the side of tube.

Hg.—Metallic mirror collecting in globules.

As.—Metallic mirror but no globules.

TEST XIII.†—**Treat the finely powdered substance in a test tube with strong HCl. Observe the result, then boil.**

Effervescence.—If the substance is non-metallic the gas given off will almost always be CO_2 showing that the substance was a carbonate. H_2S is easily recognized by its odor. Cl which is yellowish and very offensive would be given off only in a few cases by the action of some oxides on HCl.

Confirm **CO_2.**—A drop of lime water on the end of a glass rod held in the gas after it has been passed through water to free it from HCl will be rendered turbid.

Confirm **H_2S.**—A piece of filter paper moistened with lead acetate will be blackened if held in the gas.

Confirm **Cl.**—A piece of moistened red litmus paper held in the gas will be bleached.

Gelatinous Residue.—If a gelatinous residue forms after boiling away the larger part of the acid a silicate was present.

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* Other sublimates may result as noted on page 102.

† Substitute for test VIII when convenient.

SPECIAL SCHEME FOR DETECTION OF THOSE METALS WHICH WHEN PRESENT AS SILICATES USUALLY FAIL TO YIELD SATISFACTORY TESTS BEFORE THE BLOWPIPE.

Remove the volatile constituents as thoroughly as possible by roasting, then heat gently in a platinum capsule, with HF and a few drops of concentrated H_2SO_4 as long as fumes are given off; add a little more HF and H_2SO_4, and heat again in the same way. When fusion is quite cold, dissolve in cold water and filter.

Filtrate a.—Divide into four parts and test as follows:

1. Add a piece of Zn or Sn and a little HCl, and heat.

Ti.—A violet or blue solution.

CONFIRMATIONS **Ti.**—Nearly neutralize solution, and then add $Na_2S_2O_3$, and boil. White ppt. = Ti.

Or, make solution slightly alkaline, and then acidify slightly with HCl, and add Na_2HPO_4. White ppt. = Ti.

2. Add excess of KOH or NaOH, boil and filter, and to filtrate add excess of NH_4Cl. and boil.

Al.—White precipitate.

Dissolve ppt., produced by the KOH or NaOH, in HCl, and add K_4FeCy_6.

Fe.—Blue precipitate.

3. Add HCl; then make alkaline with NH_4OH and add $(NH_4)_2S$ + $(NH_4)_2CO_3$ in slight excess, filter; to filtrate add Na_2HPO_4.

Mg.—White *crystalline* precipitate.

CONFIRMATION **Mg.**—If phosphates are present, this test would not be reliable for Mg. In such cases test a few drops of the solution with H_2S; if it causes any precipitate, saturate the whole of the solution with it, filter, and to filtrate add a few drops of HNO_3, and boil to oxidize FeO, nearly neutralize with solution of Na_2CO_3. If iron is not present, add a few drops of Fe_2Cl_6, enough to give a red precipitate with the sodium acetate, then dilute and add excess of sodium acetate, and boil, filter, and to filtrate add NH_4OH + $(NH_4)_2S$, filter, to filtrate add Na_2HPO_4. White crystalline precipitate = Mg.

4. Add $BaCl_2$ as long as it gives a precipitate, then $Ba(OH)_2$ to alkaline reaction, boil, filter, and to filtrate add $(NH_4)_2CO_3$ and NH_4OH and heat, filter; evaporate filtrate to dryness and ignite to drive out NH_4 salts. Test residue in flame for K and Na; dissolve residue in a few drops of water, filter if necessary, and then add solution of $PtCl_4$ and alcohol.

K.—Yellow crystalline precipitate.

CONFIRMATION **Na, K.**—Mix 1 part of the silicate with 5–6 parts of precipitated CO_3 and 1 part of NH_4Cl, heat to redness in platinum capsule for thirty minutes ing careful to apply heat gently at first, digest sintered mass in hot water, and filter; filtrate add $(NH_4)_2CO_3$ and NH_4OH, heat and filter, evaporate filtrate to dryness and ıite gently until all ammonium salts are driven off, then determine Na and K as ove.

Residue a.—Boil with strong solution of $(NH_4)_2SO_4$ and filter.

Filtrate b.—Add a few drops of H_2S water; if any precipitate rms, saturate with H_2S and filter, and to filtrate add NH_4OH d $(NH_4)_2C_2O_4$.

Ca.—A white precipitate.

Residue b.—Moisten with concentrated HCl and try coloration flame.

Ba.—Yellowish-green flame.

Sr.—Scarlet flame.

CONFIRMATION **Ba** and **Sr.**—Fuse residue b with two to three pts. of soda in a pla- ım capsule: treat fusion with boiling water, filter, reject filtrate, dissolve residue ıcetic acid, add a few drops of H_2S water, if it gives any precipitate, saturate with S and filter, and to filtrate add $K_2Cr_2O_7$. **Ba** = yellow precipate. Filter, and to ate add $CaSO_4$ warm and let stand. **Sr** = white precipitate.

PART III.

DESCRIPTIVE MINERALOGY.

CHAPTER XV.

CHARACTERS OF MINERALS.

ALL substances *which have not been formed by living growth* be-
ng to the Mineral Kingdom of Nature; and, in the broadest
nse, mineralogy treats of ALL such substances. The magnitude
such a Science of Mineralogy has, however, forced an arbi-
ary division.

A MINERAL is now defined to be: a homogeneous substance, of
finite chemical composition, found ready-made in nature, and
t a product of life. Usually it will be a solid with a crystalline
ructure.

MINERALOGY in its arbitrarily limited sense considers the one
ousand or so accepted minerals and the many thousands of
oubtful species and varieties. Its primary purpose is the study
the elementary constitution of the minerals; their chemical
mposition as revealed by analyses; their molecular structure
revealed by crystalline form and by physical tests, and their
igin and mode of formation as revealed by associated min-
als, the alterations which they undergo and their synthetic pro-
uction.

The consideration of artificial compounds is referred to Chemistry.
lthough the chemist's laboratory and Nature employ the same
rces and produce some substances identical in all respects, the
tural substances are usually not easily imitated because the im-
ortant element of long periods of time cannot be given to the
anufacture of the substance. On the other hand most manu-
ctured compounds are too soluble and perishable to exist long
natural salts.

A ROCK is a mineral mass of fairly constant character for a co siderable depth and area. It sometimes consists entirely of o mineral, much more frequently of two or more minerals, and ma consist in part of organic remains.

The resolution of these rocks into their component minera and the study of these minerals belongs to Mineralogy. Th study of these rocks, *as such*, is referred to Petrography an Geology.

IN ELEMENTARY WORK IN MINERALOGY, especially in a techn cal course, the principal object is the acquisition of an 'ey knowledge' of the common and commercially important minerals s that they may be recognized at sight or determined rapidly by few simple tests. This knowledge can be acquired only by hand ling and testing both labelled and unlabelled specimens, and i best preceded by a thorough drill in the use of the blowpipe an a study of models and natural crystals.

CRYSTALS OF MINERALS.

Natural crystals are rarely ideal in shape and in examining then regard must be paid rather to the recurrence of similar groups o faces than to the actual position or size of the faces. Careful in spection assisted by rough measurements of prominent angles wit a hand goniometer will usually be sufficient to determine system forms, and often species.

The different crystals of any substance will usually show one o two predominating forms and if from the same locality will show an even greater constancy of habit, so that it is frequently possible to distinguish between crystals of different minerals closely alike in angle by the *habit*, that is the common association of faces.

Regular Grouping of Crystals.

The manner of the grouping of the crystals is sometimes a char acter of importance. Frequently the grouping is irregular and apparently without law, as in Fig. 308 of Tyrolese epidote, but at other times there is an evident tendency to regular arrangement. Twinning has already been described, pp. 65–71, in which the cor responding crystal axes are usually inclined to each other. A tendency to parallel arrangement of corresponding axes is also fre quently observed which may be shown either by isolated crystals with their axes parallel, as in the case of the quartz crystals

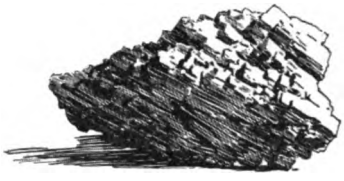
FIG. 308.

upon feldspar from Japan, shown in Fig. 309. Or the crystals may be *united* in parallel or approximately parallel position, as in the pyromorphite, from Nassau, Fig. 310.

In certain instances the union of many crystals in approximately parallel position results in one larger crystal, either of the e form with slightly curved faces as in dolomite, Fig. 311, or different form, as in the formation of octahedral fluorite by the n of cubes.

FIG. 309.

FIG. 310.



egular groupings sometimes occur which are much less simple haracter than the above, thus Dana describes * crystallized cop-

FIG. 311.

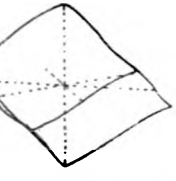


FIG. 312.

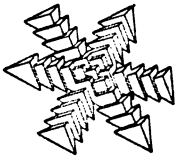


FIG. 313.

occurring in groups like Fig. 313, com-ed of cubes each twinned parallel to an hedral face and these twins united in par-l position so as to form branches at sixty rees to each other as shown in ideal form, 312.

Am. Journ. Sci., XXXII., p. 428, 1886.

Surface Irregularities.

Etchings.—The perfectly smooth and plane surface is difficult find, frequently the surfaces are more or less corroded by natu agencies, and many show natural etch figures similar to the ar ficial etch figures described on p. 148.

Striations.—Sometimes crystal faces are marked by fine par lel straight lines which are really fine "grooves" each bound by two definite crystal planes. They may result either from contest between two crystal forms as in the case of the striatio

FIG. 314.

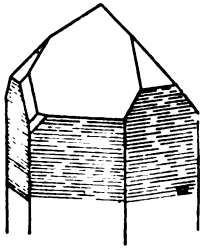
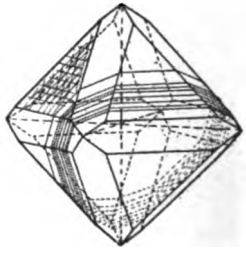


FIG. 315.



on the prism faces of quartz, Fig. 314, which are due to an alte nate formation of prism and rhombohedron. At other times t striæ are due to a repeated reversal or twinning of small individua which together make the whole crystal. If individuals 1, 3 a 5, are in normal position while the intermediate individuals 2, and 6, are in reversed position, there will usually result reentrant a salient angles. If the individuals are thin the reentrant angles b come mere furrows or striations. Fig. 315 shows twinning st ations on a magnetite crystal from Port Henry, N. Y.*

Curved Surfaces.—Crystals may appear curved because co posed of individual smaller crystals only approximately parallel

FIG. 316.

FIG. 317.

in dolomite, Fig. 311, or siderite. Sometimes there results fro this cause very peculiar shapes as in the worm-shaped crystal

* J. F. Kemp.

ndum,* Fig. 316, which is composed of layers, each a hexag-
pyramid cut off by the basal pinacoid. At other times the
ng may be due to pressure after formation, which may be
mpanied by a breaking of the crystal as in the tourmaline
317.

clusions.—Foreign substances may be shut in a crystal dur-
apid solidification as in the case of drops of water or bubbles

FIG 318.

FIG. 319.

as in quartz, or of sand in the crystals of calcite called Fon-
ebleau limestone, Fig. 318, which while retaining a form proper
alcite, contain sometimes as much as sixty per cent. of silica.
t other times the inclusions are material which the process of
tallization has tried to eliminate from the crystal. In such a
the included material is apt to be definitely arranged as in the
of the magnetite in mica from Chandler's Hollow, Del.,† in
h the magnetite is deposited on the cleavage planes of the
and parallel to the mica prism of 120 degrees. This is also

FIG. 320.

trated by the regular grouping of the purer white and less pure
portions in chiastolite as shown in successive sections of a
tal in Fig 320.

H. Barvir, Beiträge zur Morphologie des Korund, *Ann. K. K. Hofmuseums*, 1892, p. 141.

Huntington, *Am. J. Sci.*, XXXII., 301, 1886.

FIG. 321.

At times definite minerals are included such as the little curved crystals of prochlorite (helminth), Fig. 321, frequently found in quartz and feldspar, or the magnetite in mica just mentioned, while at other times the inclusions may be microscopic crystals (microlites) or incipient crystals (crystallites) not easily identified.

CRYSTALLINE AGGREGATES.

While the definite crystal is the simplest proof of that regular arragement of particles which is called a crystalline structure this structure usually exists even in masses which do not show a single crystal face. This is often proved by the fact that either the entire mass may be split (cleaved) parallel to definite planes or different portions may each be so split parallel to its own set of planes. Mineral masses which are not opaque if examined by polarized light, as explained later, produce effects upon the light entirely different from those produced by a substance with indefinitely arranged particles, and in opaques masses the regular structure may be proved by other physical tests.

Massive and Amorphous.

All masses which do not show definite crystal faces are said to be *massive*, whether crystalline in structure or not. If cleavage, polarized light and other tests fail to prove any crystalline structure, the mineral is said to be amorphous. The number of minerals accepted as amorphous is exceedingly small, but certain varieties of minerals which crystallize may, from rapid cooling or other cause, be apparently amorphous.

Columnar Structure.

The structure is said to be columnar when the imperfectly formed crystals are relatively long in one direction and grouped.

FIG. 322.

FIG. 323.

FIG. 324.

g. 322 shows a columnar beryl. The columns may be parallel not.

Bladed.—A variety of columnar in which the columns are flat-ed like a knife blade, as in cyanite.

Fibrous.—A variety of columnar in which the columns are slen- threads or filaments, as in Fig. 323, of the serpentine asbestos Quebec, Canada.

mellar Structure.

The structure is said to be lamellar when the imperfectly formed stals appear as layers or plates, either straight or curved, as in mineral talc, Fig. 324.

Foliated.—A variety of lamellar, in which the plates separate ily.

Micaceous.—A variety of lamellar in which the leaves can be ained extremely thin, as in the micas.

anular Structures.

The structure is said to be granular when the partially formed stals appear as aggregations of angular grains, which may be *rse* or *fine*, as in the marbles.

Impalpable.—A variety of granular in which the grains are in-ble to the unassisted eye.

itative Shapes.

Many terms are used, based upon a fancied resemblance to some ural object. The more important of these are:

Reniform.—With the general shape of a kidney, as in hema- Fig. 325.

FIG. 325

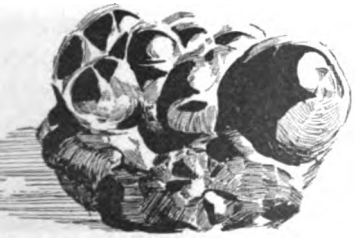


FIG. 326.

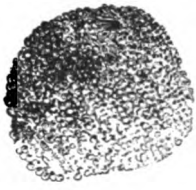
Botryoidal.—Having something of the appearance of a bunch of pes, being made up of several globular individuals close to-her, as in chalcedony, Fig. 326.

Nodular—Occurring in separate rounded individual lumps or dules.

Mammillary.—With low and broad rounded protuberances. Used for larger, flatter roundings than botryoidal.

Oölitic.—Composed of small rounded grains like the roe of a fish, as in varieties of calcite and hematite, or the hyalite from Japan, Fig. 327.

FIG. 327.



Pisolitic.—Similar to oölitic, but the grains larger, the size of a pea.

Stalactitic.—In hanging cones or cylinders like icicles, as in calcite or limonite, Fig. 328.

FIG. 328.

Acicular.—Rigid and slender like a needle.

Capillary.—Fine like hair.

Plumose.—Like a feather, as in a variety of mica from Minot, Me., Fig. 329.

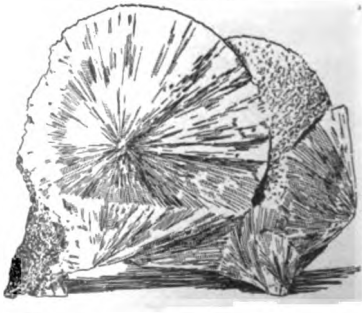
Sheaf like.—Resembling a sheaf of wheat, as in Fig. 650, of stilbite.

FIG. 329.

Reticulated.—Crossing like the meshes of a net, as in Fig. 462, of stibnite.

FIG. 330.

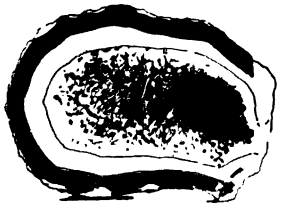
FIG. 331.



Arborescent or Dendritic.—Branching like a tree as in copper, Fig. 313, or pyrolusite, Fig. 330.

Radiating.—Diverging from a common center, sometimes forming nearly complete spheres, as in pectolite from Paterson, Fig. 1. More frequently forming partial spheres, as shown in wavellite, Fig. 553, pectolite of Bergen Hill, Fig. 602.

FIG. 332.



Drusy.—Closely covered with minute crystals, giving a rough surface like sandpaper.

Geode.—A hollow nodule lined with crystals, as in the quartz geode, Fig. 332.

Incrustation.—A coating or crust.

HARDNESS.

The resistance of a smooth plane surface to abrasion is called hardness, and is commonly recorded * in terms of a scale of ten common minerals selected by Mohs:

1. *Talc*, laminated.
2. *Gypsum*, crystallized.
3. *Calcite*, transparent.
4. *Fluorite*, crystalline.
5. *Apatite*, transparent.
6. *Orthoclase*, white cleavable.
7. *Quartz*, transparent.
8. *Topaz*, transparent.
9. *Sapphire*, cleavable.
10. *Diamond.*

The following scale of Chapman gives about the same results:

1. Feels soft and greasy and is easily scratched by the finger-nail.
2. Just scratched by the finger-nail.
3. Scratches and is scratched by a copper coin.
4. Not scratched by copper, but does not scratch glass.
5. Just scratches glass; easily scratched by a knife.
6. Scratches glass easily. Just scratched by a file.

7–10. Not scratched by a knife.

A sharp corner of the substance tested is drawn across successive members of the scale, from 10 down, until one is found to be scratched. Some inconspicuous but smooth surface of the sub-

* In more exact testing the crystal may be moved on a little carriage under a fixed vertical cutting point and the pressure determined, which is necessary to produce a visible scratch. Other methods are planing or boring with a diamond splinter under constant pressure, and comparing the loss in weight for a given penetration or given number of movements. The loss of weight during grinding and the pressure necessary to produce a permanent indentation or a crack have also been used as determinants of hardness.

stance is then selected and a sharp corner of the scratched standard mineral is moved back and forth several times on the same line a short distance ($\frac{1}{8}$ inch) across the surface. If the mineral is not scratched it is harder than the standard used, and the next higher on the scale should be tried in the same way.

If the mineral is scratched it is of about the same hardness of the standard. Care must be taken to distinguish between a true scratch and the production of a "chalk" mark which rubs off. Altered surfaces must be avoided.

Or the knife may be used first, the hardness approximately judged by the ease with which it cuts the mineral and checked by the nearest member of the scale. If the knife does not scratch the specimen the harder members, 6 to 10, are used successively until one is found which scratches the mineral.

TENACITY.

A mineral is said to be

Brittle, when it breaks to powder before a knife or hammer and cannot be shaved off in slices.

Sectile, when small shavings or slices can be shaved off which, however, crumble when hammered.

Malleable, when slices can be shaved off which will flatten under the hammer.

Elastic, when a thin plate will bend and then spring back to its original position when the bending force is removed.

Flexible, when a thin plate will bend without breaking.

CLEAVAGE.

Many crystals break or *cleave* along more or less smooth plane surfaces in certain directions more readily than in other directions, and it is found that these directions of cleavage are always parallel to faces of forms in which the substance can crystallize.

A cleavage face may usually be distinguished from a crystal face by its splintery character, and cleavage is often indicated by a pearly lustre on a face of the crystal parallel to the cleavage direction, the lustre being due to repeated light reflections from cleavage rifts.

True cleavage is obtained with equal ease at any part of a crystal, and there is only a mechanical limit in the closeness of

e cleavage to the next. The quarter undulation mica plate, for stance, is a cleavage of mica of about $\frac{33}{10000}$ mm. in thickness. When cleavage is obtained parallel to one face of a crystal form will be obtained with equal ease parallel to all faces of the form. r instance, galenite cleaves parallel to all planes of the cube, cite in three directions parallel to the faces of a rhombohedron h diedral angles of 105° 5′, as shown in g. 333 and barite in two directions parallel the faces of a prism with an angle of 101° ′.

FIG. 333.

Cleavage may be obtained parallel to the es of two or more separate crystal forms, instance barite also cleaves parallel to the se, giving as a result of both cleavages a ape precisely that of Fig. 191.

The cleavage angles are as exact as the angles between crys- faces, and as they can easily be obtained from any of the ny possible crystal forms and frequently from the masses, the gles of cleavage as well as the ease of cleavage are useful char- ters in determination.

Cleavage is, in general, limited to directions parallel to the mpler and more frequently occurring crystal forms. In the *metric system* it is parallel to the cube, octahedron or dodecahe- on. In the *tetragonal system* it is basal or prismatic and only ely pyramidal. In the *hexagonal system* it is basal, prismatic rhombohedral but rarely pyramidal.

In the other systems the arbitrary selection of axes prevents a mple classification of the cleavages, but the selection usually kes one direction of cleavage pinacoidal and two of equal ease smatic. The cleavage form is usually chosen as the unit form.

Cleavage is said to be *perfect* or *eminent* when obtained with eat ease, affording smooth, lustrous surfaces. Inferior degrees ease of cleavage are called *distinct*, *indistinct* or *imperfect*, *inter- pted*, *in traces*, *difficult*.

Cleavage is usually obtained by placing the edge of a knife or all chisel upon the mineral parallel to the supposed direction of eavage and striking a quick, sharp blow upon it with a hammer. some instances the cleavage is produced by heating and sud- nly plunging the mineral in cold water.

Frequently the cleavage is made apparent during the grinding a thin section.

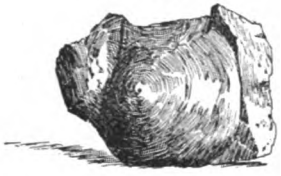
Sudden heat alone will often produce decrepitation and with easily cleavable minerals the fragments will be cleavage forms.

FRACTURE.

When the surface obtained by breaking is not a plane or a step-like aggregation of planes it is called a *fracture* and described as:

Conchoidal, rounded and curved like a shell, Fig. 334.

FIG. 334.



Even, approximately plane.

Uneven, rough and irregular.

Hackly, with jagged sharp points and depressions as with metals.

Splintery, with partially separated splinters or fibres.

GLIDING PLANES.

In a few minerals, calcite, pyroxene, stibnite, halite, etc., it has been observed that pressure in certain directions will either produce a separation along a definite plane, which is not a true cleavage plane, or else will develop a twin structure (secondary twinning) with this "gliding plane" as the twin plane.

If a cleavage of Iceland spar is placed, as in Fig. 335, with an edge *ad* of the larger angle resting upon a steady support and the

FIG. 335.

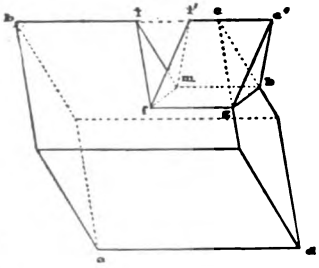


FIG. 336.

blade of a knife is pressed steadily, as by a vise, at some point of the opposite edge, the portion of the crystal between *i* and *c* will be slowly pushed into a new position of equilibrium as if by rotation about *fghm* until the new face *gc'h* and the old face *gch* make equal angles with *fghm*.

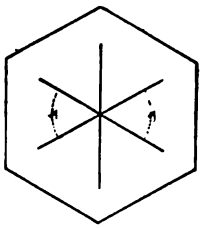
PARTING.

The planes along which a gliding has occurred may thereafter
planes of easy separation or *Parting*,* differing from true cleav-
e, however, because in parting the easy separation is limited to
e planes of actual gliding, while true cleavage is obtained with
ual ease at all other parallel planes. Fig. 336 shows parting in
roxene.

PERCUSSION FIGURES.

If a pin or a rod with a slightly rounded point is pressed against
firmly supported plate of mica and sharply tapped with a light
mmer, three planes of easy separation will
indicated by little cracks radiating † from
e point, Fig. 337, the most distinct of which
always parallel to the clino pinacoid, the
hers at an angle x thereto which is 53° to
5° in muscovite, 59° in lepidolite, 60° in
otite, 61° to 63° for phlogopite.

FIG. 337.



In the same way on cube faces of halite a
oss is developed with arms parallel to the
agonals of the face. On an octahedral face a three-rayed star
developed.

ETCHING FIGURES.

When a crystal or cleavage is attacked by any solvent the action
roceeds with different velocities in crystallographically different
rections, and if stopped before the solution has proceeded far, the
ystal faces are found to be pitted with little cavities of definite
ape.

The absolute shape varies with many conditions; time, tempera-
re, solvent, crystallographic orientation and chemical composition.
The figures, whatever their shape, conform in symmetry to the
ass to which the crystal belongs, and are rarely forms common
several classes. They are alike on faces of the same crystal
rm and generally unlike on faces of different forms, and serve,
herefore, as an important means (perhaps the *most* important) for
etermining the true grade of symmetry of a crystal and also for
ecognizing and distinguishing faces.

* Similar planes of easy separation may be due to other causes, for instance, during
e growth of a crystal the planes at certain intervals may be coated with dust or fine
mellæ of a foreign substance and later the crystal may grow further. This may be
peated several times, forming thus parallel planes of easy separation, *e. g.*, capped quartz.

† By pressure alone three cracks diagonal to these are developed.

Fig. 338 shows the shape and direction of the etchings upo cube of pyrite. These conform to the symmetry of the group the diploid, p. 21. On the other hand the etchings upon a cu

FIG. 338.

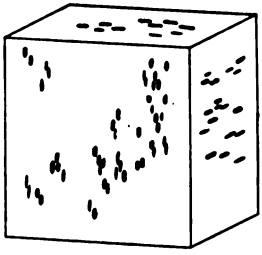
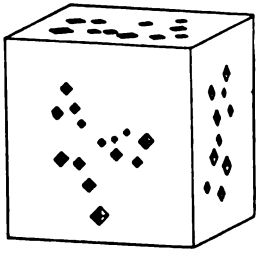


FIG. 339.



of fluorite, Fig. 339, show a higher symmetry corresponding that of the hexoctahedral group, p. 12.

The etchings of wulfenite, Fig. 341, show the mineral to belo to a class of lower symmetry than that suggested by the for

FIG. 340.

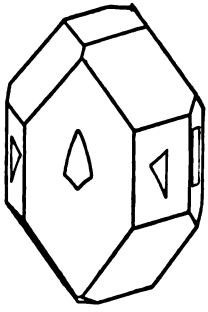
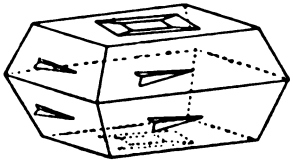


FIG. 341.



while the etchings of pyroxene, Fig. 340, like the form are sy metrical to one plane.

SPECIFIC GRAVITY.

The specific gravity of a substance is its weight divided by t weight of an equal volume of distilled water.

The Jolly balance, Fig. 342, is a simple piece of apparatus f obtaining the specific gravity of a solid. The lower scale pan *kept submerged;* three readings are made by noting the heights which the index on the wire and its image in the graduated mirr coincide with the line of sight when the spiral comes to rest.

A. Instrument reading with nothing in either scale pan.

B. Reading with mineral in upper scale pan.

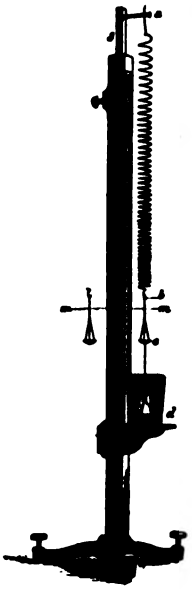
C. Reading with same fragment transferred to lower scale pan.

$$\frac{B-A}{B-C} = \text{Specific Gravity.}$$

In using an ordinary chemical balance the fragment is first weighed and then suspended from one scale pan, by a hair, or very fine platinum wire, in a glass of water and reweighed. The weight of platinum wire must be deducted.

$$\text{Specific Gravity} = \frac{\text{Wt. in air}}{\text{Wt. air} - (\text{Wt. water} - \text{Wt. wire})}.$$

FIG. 342.



Very porous minerals and powders are determined by weighing in a little glass bottle the stopper of which ends in a fine tube. The mineral is weighed and the bottle full of water is also weighed. The mineral is then added to the bottle and displaces its bulk of water, and the differenee between the weight and the sum of the other two weights is the weight of the displaced water.

The material must be pure and for careful work should be boiled to expel air and allowed to cool in the water.

Use of Heavy Liquids.

There have been used for specific gravity determinations, but more especially for separating minerals of different specific gravities, a number of different liquids of which the best are :

Thoulet Solution.—Mercuric iodide and potassium iodide, in the ratio of five parts to four by weight, are heated with a little water until a crystalline scum forms, then filtered. The maximum specific gravity is nearly 3.2 and may be lowered by the addition of water to any desired point.

Klein Solution.—Cadmium borotungstate with a maximum specific gravity of 3.6.

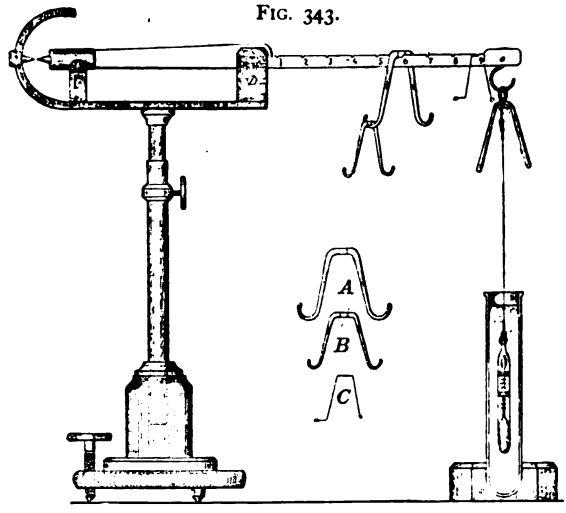
Braun's Solution.—Methylene iodide CH_2I_2 with a maximum specific gravity of 3.32 which can be lowered by the addition of toluol.

Penfield Solution.—Silver thallium nitrate which is liquid at 75° C., has a maximum specific gravity of over 4.5 which can be lowered by the addition of hot water.

In all of these the method of determining the specific gravity of a mineral, necessarily lighter than the liquid, is to add the diluent drop by drop until the mineral fragment will *just* float or if pushed in will stay wherever pushed.

For determining the specific gravity of the liquid the most convenient balance is that of Westphal, Fig. 343. The beam is graduated in tenths and the weights *A*, *B* and *C* are respectively unit, $\frac{1}{10}$ and $\frac{1}{100}$.

FIG. 343.



The balance is so constructed that when the thermometer float is suspended in distilled water at 15° C. a unit weight must be hung at the hook to obtain equilibrium.

If then the test tube is nearly filled with the heavy liquid and weights added until equilibrium is secured the specific gravity is known.

For instance in the figure the weights employed are :

Unit weight at hook, value.....	1.000
Unit weight at sixth division, value	0.600
$\frac{1}{10}$ weight at sixth division, value.	0.060
$\frac{1}{100}$ weight at ninth division, value	0.009
Specific gravity.....	1.669

For rough determinations a series of stoppered tubes containing lutions of known density is very convenient.

TASTE.

Some minerals have a decided taste which is usually either:
Astringent, the taste of alum.
Saline or Salty, the taste of common salt.
Bitter, the taste of epsom salts.
Alkaline, the taste of soda.
Acid, the taste of sulphuric acid.
Cooling, the taste of nitre.
Pungent, the taste of sal-ammoniac.

ODOR.

Odors are rarely obtained from minerals, except by setting free me volatile constituent. The terms most used are:
Garlic, the odor of garlic obtained by heating minerals containg arsenic.
Horseradish, the odor of decayed horseradish obtained from inerals containing selenium.
Sulphurous, the odor obtained by heating sulphur or sulphides.
Fetid, the odor obtained by dissolving sulphides in acid.
Bituminous, the odor of bitumen.
Argillaceous, obtained from serpentine and some allied minerals, ter moistening with the breath.

FEEL.

Terms indicating the sense of touch are sometimes useful.
Smooth, like celadonite or sepiolite.
Soapy, like talc.
Harsh or Meagre, like aluminite.
Cold, distinguishes gems from glass.
Adheres to tongue.

CHAPTER XVI.

OPTICAL CHARACTERS.

LUSTRE.

The lustre of a mineral is dependent principally upon refractiv power but in part upon its transparency and structure. It may b called the *kind* of brilliancy or shine of the mineral.

METALLIC lustre is the lustre of metals. It is exhibited onl by opaque minerals.

NON-METALLIC lustre is exhibited by all transparent or trans lucent minerals. It may be vitreous, adamantine, resinous, pearly silky, greasy or waxy.

Vitreous, the lustre of a fractured surface of glass or of quart crystals.

Adamantine, the almost oily lustre of the uncut diamond o cerussite, exhibited by minerals of high idex of refraction.

Resinous, the lustre of resin or sphalerite.

Greasy, the lustre of oiled glass or elaeolite.

Pearly, the lustre of the mother of pearl or of foliated talc Common parallel to a very perfect cleavage.

Silky, the lustre of silk or of satin spar, requires a fibrous struc ture.

Dull. Without lustre or shine of any kind. Kaolin is a good example.

The prefix sub, as sub-metallic, sub-vitreous, is used to expres an imperfect lustre of the kind.

The words splendent, shining, glistening, glimmering and dul are terms of *intensity* dependent on the quantity of light reflected

Lustre should, when possible, be determined by a comparison with minerals of known lustre, and should always be observed on a fresh or unaltered surface.

The degree or kind of lustre is always the same on like faces o the crystal, but may be different on unlike faces, as in the pearly basal plane of apophyllite and the vitreous prismatic faces.

COLOR.

The color of minerals is one of their least definite characteristics, en varying with different specimens of the same species, and metimes within the widest limits. Minerals of metallic or sub-etallic lustre vary much less in color than non-metallic minerals d their color is, therefore, a more useful characteristic. It varies m tarnish and should be observed on fresh fracture.

In describing color, white, gray, brown, black, blue, green, yel-v and red are used, often with prefixes, which suggest the color some familiar object. These need no explanation.

Play or Change of Colors.—A more or less rapid succession of ismatic colors appearing as the mineral is turned.

Iridescence.—Prismatic colors, either from the interior of a min-al, as from a thin film of air between cleavages; or an external in film due to some coating or alteration.

Color is frequently due to a few hundredths of one per nt. of some organic or, more rarely, inorganic substance dissolved the mineral, or it may be due to larger amounts of mechan-lly included foreign material.

Tarnish.—A surface which has been exposed to the air or to oisture is often of different color from the fresh fracture.

Opalescence.—A milky or pearly reflection, sometimes an effect crystalline structure at other times due to fibrous inclusions.

Asterism.—A star effect by reflected light as in the ruby or by nsmitted light as in mica and due to structure planes or symmet-ally arranged inclusions.

Phosphorescence.—The emission of light by a substance after posure to light, heat, friction, mechanical force, or an electrical scharge.

Fluorescence.—The emission of light *during* an exposure to ght as when colorless fluorite colors a ray of sunlight pale violet.

STREAK.

The streak of a mineral is the color of its fine powder. It is ually obtained by rubbing the mineral on a piece of hard white aterial such as novaculite or unglazed porcelain, or it may be otained less perfectly by scratching the mineral with a knife or e, or by finely pulverizing a fragment of the specimen. The reak often varies widely from the color of the mass and is nearly

constant for any species. When not white it is a characteristi very useful in determination.

TRANSLUCENCY.

The translucency of a mineral is its capacity to transmit ligh A mineral is said to be :

Transparent, when objects can be seen through it with clearnes

Subtransparent, when objects can be indistinctly seen through i

Translucent, when light passes through, as through thin porce lain, not enough to distinguish objects.

Subtranslucent, when only the thin edges permit any light t pass.

Opaque, when no light appears to pass even through thin edge

THE OPTICAL CHARACTERS AS INDICATORS OF CRYSTALLIN STRUCTURE.

Light is transmitted in straight lines by vibrations of a so-calle "*ether*" which fills all space even between the particles of solids

REFRACTION.

When a ray of light passes from one substance into another i which its velocity is different, the ray is bent or refracted.

Index of Refraction.

The amount of bending * is found to be such that whatever th direction of the incident ray, $\frac{v_1}{v_2} = \frac{\sin i}{\sin \rho}$ that is the ratio betwee the sines of the angles of incidence and refraction is constant an is called the *Index of Refraction* of the second substance wit respect to the first.

Usually the index recorded is that of the second substance wit respect to air. Denoting the velocity in air by v and the indice

* The amount of bending may be graphically found by the construction of Snel lius, Fig. 344, R_1 is a sphere with radius the index of refraction of outer medium, R_2, sphere with radius the index of the crystal. Prolong IO to T. Draw TS parallel th normal ON, then is OS the refracted ray, and OY the corresponding reflected ray.

In triangle OSY, $OS : OY = \sin OYS : \sin OSY$, but $OS = n$, $OY = n_1$, $OYS = OTY = i$, and $OSY = \rho$ hence substituting

$$n : n_1 = \sin \rho, \text{ or } n = n_1 \frac{\sin i}{\sin \rho}.$$

the first and second substances with respect to air by n_1 and n,

have $$n_1 = \frac{v}{v_1} \text{ and } n = \frac{v}{v'_2}$$

d substituting these values in the formula we have as the index the second substance

$$n = n_1 \frac{\sin i}{\sin \rho}.$$

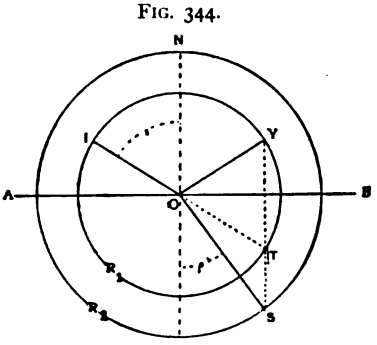


FIG. 344.

ormal Incidence.

There is no *refraction for normal incidence*, for sin $i = 0$, hence

$$n = \frac{0}{\sin \rho}$$

ich, since n is a finite quantity, only possible if $\rho = 0$.

efraction in Plane-Parallel Plates.

Since most of the tests hereafter described are made upon plates crystals with plane parallel sides, it is important to note that in ch plates the ray emerging is parallel to the entering ray, for at trance, Fig. 345,

$= n_1 \frac{\sin i}{\sin \rho}$ and at emergence $n_1 = n \frac{\sin i_1}{\sin \rho_1}$,

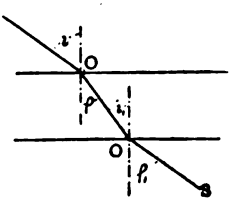


FIG. 345.

whence $$\frac{n}{n_1} = \frac{\sin i}{\sin \rho} = \frac{\sin \rho_1}{\sin i_1};$$

but $i_1 = \rho$; hence $i = \rho_1$.

TOTAL REFLECTION.

When the index of refraction n_1 of the first substance is greater an n of the second substance, there is a so-called "critical" gle of incidence for which the angle of refraction is 90°; that is, e refracted ray travels along the border surface.

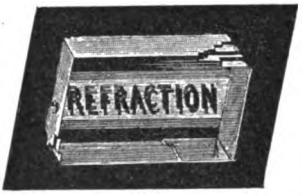
If $\rho = 90°$, sin $\rho = 1$; hence, $n = n_1 \sin i$, or $\sin i = \frac{n}{n_1}$.

For any angle of incidence greater than this the light is *totally lected.*

DOUBLE REFRACTION.

If an object is viewed through a moderately thick transparent cleavage rhomb of calcite,* it will appear to be double, as in Fig. 346. If such a cleavage is mounted so that it can be revolved about a horizontal axis normal to a vertical face, any light ray, *IT*, normally incident, Fig. 348, at the vertical face, is transmitted in the rhomb as two rays of essentially equal brightness (giving two images of any signal), and as the rhomb is turned about the axis one of these remains fixed in position, the other moves around the first.

FIG. 346.



With single refraction and normal incidence the fixed image only would have been seen, hence this is called the *ordinary* and the movable image by contrast the *extraordinary*.

FIG. 347.

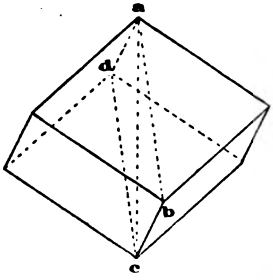
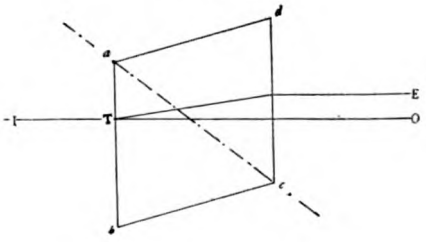


FIG. 348.



That some peculiar change has taken place other than the division of the one ray into two may be shown as follows:

Let one of the two rays be shut off and the other viewed through a second calcite rhomb similarly mounted, this ray is again split into two rays, an ordinary and an extraordinary, but these *are no longer of equal brightness*, but wax and wane in turn, the sum of their intensities remaining constant.

Planes of Vibration.

The changes in intensity as the second rhomb is turned, correspond exactly to the assumption that the vibrations of common light

* The property is common to all crystals except isometric, but calcite possesses it in a very marked degree. The double image can only be observed in a few substances, but the double refraction is better shown by the tests described later.

ve been converted by the first calcite into two sets of straight-lined orations, at right angles to each other, the one parallel to a plane rough *ac* and *IT*, Fig. 348, the other at right angles to this ane. The second calcite in the same way resolves the 'polar-ed' ray from the first into components varying in intensity ac-rding to the relative positions of the calcites.

The vibrations of *either* the extraordinary or the ordinary ray ght be parallel to *ac*, but we shall hereafter assume *that the brations of the extraordinary ray are in a plane through the axis c, d those of the ordinary are at right angles to this plane.*

On this assumption the so-called "*Plane of Polarization*" of Malus is at right angles he plane of vibration; that is, the plane of polarization of the *ordinary ray* is a ne through the axis *c*, and the plane of polarization of the *extraordinary ray* is at it angles to this. See Moses's Characters of Crystals, p. 98–100.

oduction of Plane Polarized Light.

PLANE POLARIZED LIGHT may be produced from common light.

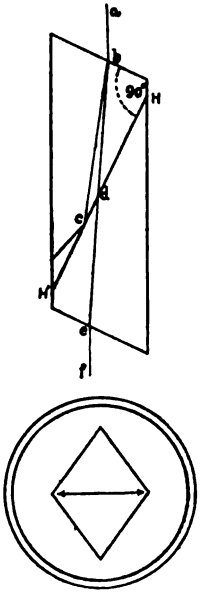
(*a*) By reflection at a particular angle of incidence (tan $i = n$), e vibrations being at right angles to the plane of reflection (plane rough incident and reflected ray).

(*b*) By refraction through a series of parallel ass plates, each plate increasing the proportion polarized light. In this case the vibrations e in the plane of reflection.

In (*a*) and (*b*) common light is always present.

(*c*) By double refraction and total reflection of e of the rays as in the so-called Nicol's prism, ade from a cleavage of calcite with a length out twice its thickness, Fig. 349.

FIG. 349.



The two small rhombic faces at 71° to the edge are ground ly and replaced by faces at 68° to the edge. The prism is n cut through by a plane at right angles both to the new ter-al faces and to the principal section. The parts are carefully ished and cemented by Canada balsam, the index of refrac-of which is 1.54 or about that of the extraordinary ray *bd*, ich, therefore, passes through the balsam with but little nge in direction; the ordinary ray *bc*, however, with an index efraction of 1.658, being incident at an angle greater than its ical angle, is totally reflected.

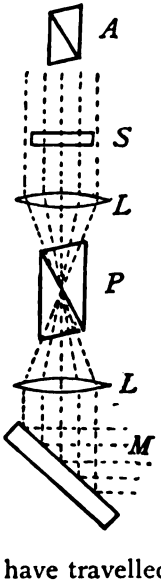
The vibration direction of the emerging light parallel to the shorter diagonal of the face of the nicol, as shown the arrow.

(*d*) By double refraction and absorption. Certain substances absorb one ray much more rapidly than the other, hence thicknesses can be chosen for which one ray is totally absorbed, the other being partially transmitted with vibrations all in one plane. Tourmaline is often used, as in this mineral the ordinary ray is much the more rapidly absorbed.

Polariscope for Parallel Light.

The essentials of a polariscope for parallel light are shown in Fig. 350. The mirror *M* sends parallel rays through the lower lens *L*, which concentrates them at the center of the polarizer *P*; this point is also the focus of the equivalent upper lens *L*. On emergence from *L* the rays are again parallel, and undergo double refraction in the plate *S* of the substance. At whatever angle the parallel rays are incident at the plate *S*, each ray, as *AB*, Fig. 351, is broken into two rays *BC* and *BD*, vibrating in planes at right angles to each other and following different paths in the plate. On emergence they follow parallel paths. Among the incident rays there are rays *EG* and *FH* such that the ordinary component of *FH* will emerge at *D* with the extraordinary of *AB* and the extraordinary component of *EG* will emerge at *C* with the ordinary of *AB*.

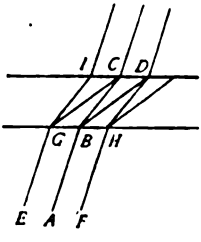
FIG. 350.



That is from every point of the upper surface there will emerge the ordinary component of one ray and the extraordinary of another, and these rays will have travelled over slightly different paths in the plate with different velocities, their vibrations being at right angles to each other.

To produce an interference effect these vibrations must be made parallel. A second polarizer, *A*, called an analyzer is, therefore, placed in the path of these rays and resolves them into components, the vibrations of which are in and at right angles to the plane of vibration of *A*, and only the former are transmitted. That is, there emerge from *A* rays advancing in the same line and with parallel vibrations. If these vibrations are alike in phase the intensity of the resultant ray will be proportionate to the square of the SUM of their ampli-

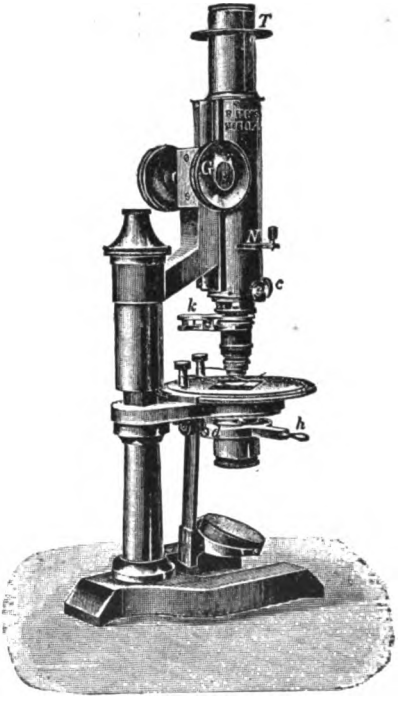
FIG. 351.



des, but if unlike in phase the intensity will be proportionate to e square of their DIFFERENCE.

The usual apparatus employed for parallel light effects is a polar-ng (or petrographical) microscope. Fig. 352, shows the most re-nt simple type of Fuess. The wer nicol is raised or lowered the lever *h*, the objective is ld in place by the clip *k* and is ntered by the screws *c*. The per nicol *N* is thrown in or out a horizontal motion and the lescope is raised or lowered.

FIG. 352.



Convergent light effects are tained with a high power ob-ctive, by swinging a small con-rgent lens over the lower nicol, a lever not shown, raising e nicol by *h* till it touches the ns, removing the eye piece and oking into the tube.

"Extinction" and "Interference" Between Crossed Nicols.

When the planes of vibration of e polarizer *P* and analyzer *A* are right angles the arrangement usually described as "crossed icols" without regard to the type of polarizer. It is evident that, ith crossed nicols none of the light from the polarizer can pene-ate the analyzer and the field must be dark. If the doubly re-acting crystal section *S*, Fig. 350, is introduced between the nicols, e field can only remain dark when the planes of vibration of ys *produced in the section* coincide with the planes of vibration f the nicols. By rotating the stage of the microscope these so-alled *extinction directions* are found by the darkening of the field. or all other positions the field will be illuminated by the compo-ents of the rays which penetrate the analyzer and this brighten-ng will be most intense for the diagonal positions.

With monochromatic light the field will also be darkened, be-ause of destructive interference, whenever the faster of each pair

of rays is just one, two, three, etc., wave lengths, of the light used ahead of the slower ray for, Fig. 353, if PP and AA are the vibration directions of polarizer and analyzer and RR, DD those of the plate, then, since the vibrations are in the same phase, the components on PP will be Or and Os which in turn yield components on AA of Oa and Oa_1, ***equal and opposite.*** That is the light vibration is stopped.

FIG. 353.

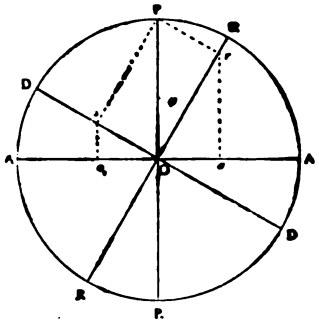
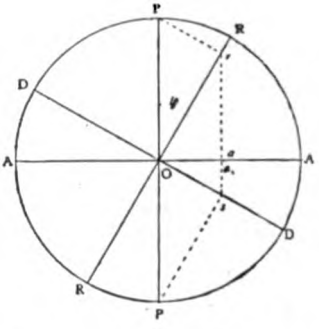


FIG. 354.

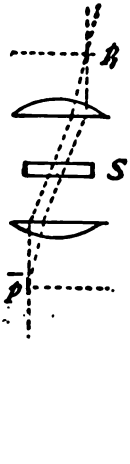


On the contrary the field will be brightest when the faster ray is ahead $\frac{1}{2}\lambda$, $\frac{3}{2}\lambda$, $\frac{5}{2}\lambda$, etc., for in Fig. 354, since the vibrations are in opposite phase, the components of PP are Or and Os and yield as components on AA, Oa and Oa_1 ***equal*** *and in the same direction.*

A wedge of doubly refracting substance, since the difference in path must increase with the thickness, will show, in monochromatic light, dark bands at regular intervals, varying with the color of the light used and corresponding to differences between the emerging rays of one, two, three, etc., wave lengths.

FIG. 355.

FIG. 356.



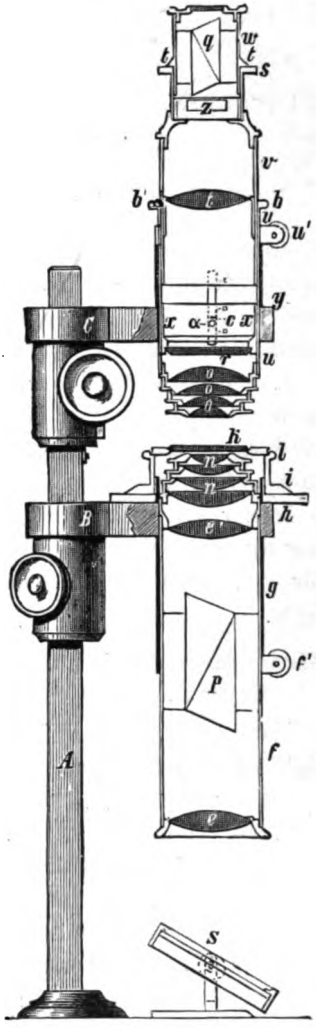
Interference Colors with White Light.

The difference between the two rays or "Retardation," $\triangle$, as it is called, depends upon three factors: (*a*) the material, (*b*) the direction of transmission or orientation, (*c*) the thickness of the section. These being known $\triangle$ is known.

But this retardation $\triangle$ may be at the same time approximately an even multiple of the wave-length of light of one color and an odd multiple of the wave-length of light of another color. That is, the light of the

st color would be very much weakened while that of the second lor would be at nearly its full intensity and instead of white light ere would result a tint due to a mbination of these and other unqually dimmed colors.

FIG. 357.



olariscope for Convergent Light.

By the addition of a lens or system lenses of short focal length just ove the plate *S* and a correspondg system just below the plate, Fig. 56, rays are simultaneously sent in any directions through the plate *S*. or each direction the same extinction nd interference phenomena occur as ere described for parallel light and ne result is an "*interference figure*" picture, the shape, brightness and nts of which depend upon the structre of the plate for all the directions aversed by the rays.

Fig. 357 shows the Norremberg olariscope arranged for convergent ght, *e*, *e'* are collecting lenses on each de of the polarizer, above *e'* are four lano convex lenses, *n*, forming the ondenser and just over these the age.

In a separate tube system above are ne objective, composed of four similar lano-convex lenses *o*, and at their cal plane the glass plate *r*, on which cross and a scale are marked; the nage there formed is magnified by *t* nd viewed through the analyzer *q*.

By removal of *n*, *o*, *r* and *t* the apparatus yields parallel rays.

CHAPTER XVII.

OPTICAL CHARACTERISTICS OF THE DIFFERENT CRYSTAL SYSTEMS.

OPTICALLY ISOTROPIC (ISOMETRIC) CRYSTALS.

Any homogeneous isometric crystal will show the same optical properties in all directions, that is, will be optically *isotropic*, and will be singly refracting* with the index of refraction constant for all directions in the crystal.

It is evident, therefore, that there can be no interference phenomenon produced when a plate from an isometric crystal is viewed between crossed nicols and since the plate will transmit vibrations in any direction with equal facility the light from the polarizer will be transmitted without change and will all be shut out by the analyzer. *That is, the field will remain dark whatever the position of the plate, both in parallel and convergent polarized light.*

Measurement of the Index of Refraction of an Isometric Crystal.

Each substance will have its characteristic index of refraction for light of each wave length, which may be determined either:

(*a*) By measuring‡ the "angle of *least* deviation" in a prism with the goniometer, Fig. 273, or a similar instrument. That is a ray of monochromatic light entering at one face of a prism of known angle, and emerging at the other will be deviated from its course. For one position of the prism, found by trial, this deviation δ is a minimum and bears a definite relation to the index of refraction n and the angle of the prism x expressed by

$$n = \frac{\sin \frac{1}{2}(\delta + x)}{\sin \frac{1}{2} x}.$$

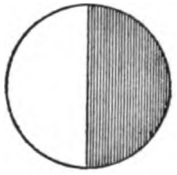
* With the exception of certain salts the crystals of which show in every direction the phenomenon called circular polarization.

† A. J. Moses *Characters of Crystals* pp. 95 and 122.

‡ *Ibid*, p. 88.

(*b*) By measuring the angle of total reflection* in a polished plane surface. The crystal plate is suspended so as to revolve about a vertical axis in a plane fronted vessel filled with a liquid of higher refractive index than the crystal. Diffused light is admitted to the vessel from the side and the crystal is viewed by a telescope fixed normal to the plane front. For *one* position the field of the telescope appears as in Fig. 358. The light is then admitted at the opposite side and the plate turned until the field is again half light half dark. The angle between these two positions is twice the critical angle, and the index of the solid is given by $n = n_1 \sin i$ in which n_1 is the known index of the liquid.

FIG. 358.



Corrections have to be made if the temperature varies, as this changes the index n_1 of the liquid.

OPTICALLY UNIAXIAL CRYSTALS.

TETRAGONAL AND HEXAGONAL CRYSTALS.

By measurement of the indices of refraction of tetragonal and hexagonal crystals for different directions of transmission it is found;

1°. That rays transmitted in the direction of the vertical axis are singly refracted, but rays in all other directions are doubly refracted.

2°. That the index of refraction of the ordinary ray is constant for all directions of transmission.

3°. That the index of refraction of the extraordinary ray is always the same for directions making equal angles with the vertical crystal axis c, but varies with directions at different angles. For the direction parallel to $\dot{c}$ it is equal to that of the ordinary and differs most from the ordinary for the direction at right angles to $\dot{c}$.

Optic Axis and Optical Principal Sections.

The crystal axis $\dot{c}$ is evidently an axis of optical isotropy, and is called the OPTIC AXIS, and any plane through it is an optical principal section.

* *Ibid*, p. 90–95.

Positive and Negative Crystals.

Let $\mathfrak{a}$ and $\mathfrak{c}$ denote * the vibration directions of the fastest and slowest rays, that is of the two rays transmitted normal to the optic axis. Then arbitrarily the distinction is made $+ = \mathfrak{c} \parallel c$ and $- = \mathfrak{a} \parallel c$. That is in positive crystals the vibration direction of the *slowest* ray is parallel to the optic axis, while in negative crystals the vibration direction of the *fastest* ray is parallel to the optic axis.

Or if ω and ε are the indices of refraction of the corresponding ordinary and extraordinary rays, the above convention would mean† Positive $\varepsilon > \omega$. Negative $\omega > \varepsilon$.

Strength of Double Refraction.

The value of $\gamma - \alpha$ is called the "strength of double refraction" or frequently the "double refraction" of the mineral and is an important character.

Measurements of Principal Indices of Refraction.

The indices α and γ of the fastest and slowest transmitted rays may be obtained by either of the methods described, on the following page, provided the direction of transmission, is at right angles to the optic axis. Two images (or limit lines) will be obtained, which may be in the field of the telescope at the same time, or may be wide apart. These may be distinguished by a nicol's prism, which transmits vibrations parallel to its shorter diagonal. The character results from $\mathfrak{c} \parallel c = +$ or $\mathfrak{a} \parallel c = -$.

INTERFERENCE PHENOMENA BETWEEN CROSSED NICOLS WITH PARALLEL POLARIZED LIGHT.

The polarizing microscope is nearly always used, the cross hairs being parallel to the vibration planes of the polarizer and analyzer. Sections of the crystals are cut with parallel faces, normal to the desired direction of transmission, and are revolved upon the microscope stage.

In sections normal to the optic axis the field remains dark throughout the entire rotation of the stage.

In all other sections there is double refraction. The field is dark (extinction) at intervals of 90°, and brightest at positions diagonal to these, and with white light interference colors result as described, p. 161.

* $\mathfrak{a}$ and $\mathfrak{c}$ are used frequently to denote axes of elasticity in these directions.

† Positive $\mathfrak{c}$ parallel c means extraordinary is slower, hence has larger index.

The extinction directions in tetragonal and hexagonal crys-ls are either parallel or symmetrical to cleavage cracks and crys-l outlines. Maximum darkness is not as easily judged as color, ence, if the field is make red or violet by a gypsum or a quartz st-plate, and the mineral inserted so as to only partly cover the eld, it will, for the extinction positions, appear of the same color the rest of the field.

he Interference Color as a Test.

The vibration directions of the faster and slower rays can be dis-nguished by means of the interference colors developed with white ght.

The extinction directions in the section are found and placed in iagonal position, a test plate of some mineral, in which the vibra-on directions have been distinguished and marked, is inserted be-veen the nicols (in a slot provided) with these directions also diago-al. If the interference color is thereby made higher, as shown by e color chart, the vibration directions of the corresponding rays e parallel; if the color is lowered, the corresponding directions vibration are crossed.

The test plates most used are:

QUARTER UNDULATION MICA PLATE.—A thin sheet of mica on which is marked the vibration direction of the slower ray, which in mica is the line joining the optic es. The thickness chosen corresponds to a 140 $\mu\mu$ which is $\frac{1}{4}\lambda$ for a medium yellow ght.

GYPSUM RED OF FIRST ORDER.—A thin cleavage of gypsum on which is usually rked α, the vibration direction of the faster ray. The thickness chosen corresponds an interference color of red of first order, or say 560 $\mu\mu$, which is essentially λ for a edium yellow.

The approximate retardation or difference in phase of the two rays ay also be measured by placing the extinction directions in agonal position and inserting a "wedge" with the corresponding bration directions crossed and running the color down to black.

The wedges most used are:

QUARTZ WEDGE.—A thin wedge of quartz, cut so that one face is exactly parallel the optic axis. The length of the wedge is parallel to the optic axis, and as quartz positive this direction is c, the vibration direction of the slower ray.

THE V-FEDEROW MICA WEDGE.—Fifteen quarter undulation mica plates super-sed in equivalent position, but each about 2 mm. shorter than the one beneath it.

The mica wedge inserted with corresponding vibration directions rossed over those of the section will for each interposed plate reduce by 140 $\mu\mu$. To render the field dark will require $\frac{\Delta}{140} = n$ plates. onversely $n. \times 140 = \Delta$, in which n is determined by count.

The quartz wedge similarly used will give an approximate value by counting the number of times the original color reappears, if n times, then is the color a red, blue, green, etc., of $n + 1$ order, for which the value may be looked up in a chart.

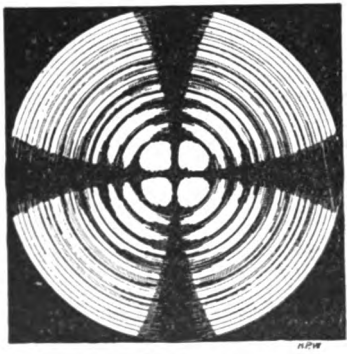
The approximate strength of the double refraction will result by dividing the value of Δ by the thickness of the section in millionths of a millimeter.

INTERFERENCE PHENOMENA BETWEEN CROSSED NICOLS WITH CONVERGENT LIGHT.

In sections normal to the optic axis with monochromatic light there will always appear a dark cross, the arms of which intersect in the center of the field, and remain parallel to the vibration planes of the nicols during rotation of the section.

Any ray will vibrate either in or normal to a plane through the ray and the optic axis. Hence the rays transmitted parallel to the vibration planes of the crossed nicols have their vibrations in these planes and are totally extinguished. As the stage is rotated successive rays come into these positions maintaining the same effect.

FIG. 359.



Destructive interference will take place at those points at which the "Retardation Δ" is equal to one, two or three, etc., wave lengths of the light used, p. 161. Therefore, because the optic axis is an axis of isotropy, there will be dark *circular* rings around the center of the cross at distances apart varying with the crystal and the thickness of the crystal section. In sections of the same mineral the thicker the section the closer the rings, while in sections of different minerals but equal thickness the greater the value of $\gamma - \alpha$ the closer the rings.

With white light the rings become rings of color corresponding to the Newton colors.

Determination of Optical Character of Crystal.

The MICA TEST PLATE inserted above a section normal to the optic axis with its direction c diagonal to the nicols will destroy the

* A. J. Moses Characters of Crystals, p. 103.

ck cross and break the rings into four quadrants, the relative
cts in positive and negative crystals being shown in Figs. 360,
1. The corresponding signs + and — are suggested by the

FIG. 360.

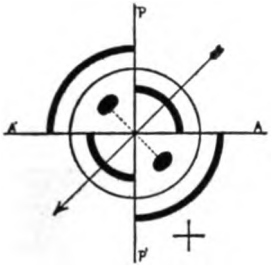
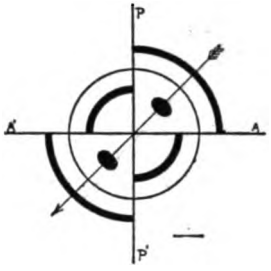


FIG. 361.



ative positions of the dark flecks and the arrow showing the
ection c of the test plate.

When the rings are almost or quite out of the field it is
ore convenient to insert a gypsum (red of first order) plate with
direction a in diagonal position, the effect being that "blue
adrants" correspond in position to the black flecks. This de-
mination must be made in white light.

UNIAXIAL CIRCULARLY POLARIZING CRYSTALS.

Certain hexagonal and tetragonal crystals, notably those of quartz,
e circularly polarizing in the direction of the optic axis though
other respects they act optically like other uniaxial crystals.

With Parallel Monochromatic Light and Crossed Nicols.

In sections normal to the optic axis the light is not extin-
ished until the analyzer has been turned a definite number of
grees dependent upon the thickness of the section and the wave
ngth.

The direction in which it is necessary to turn the analyzer to
ange violet into red is the so-called direction of rotation.

With Parallel White Light and Crossed Nicols.

The shorter the wave length the greater the rotation, that is the
fferent colors are dispersed and on emergence vibrate in different
anes. As the analyzer is turned its plane of vibration is succes-
vely at right angles to the planes of vibration of the different
olors. That is, at any time only one color is shut out completely

and the rest in varying degree. The color with vibrations mos nearly parallel to the vibration planes of the analyzer will be lea shut out and will determine the predominating tint in the resultar color.

Fig. 362 shows the rotations produced by a quartz plate of 3.7 mm. thickness. The vibration plane of yellow is, for this thick ness, at right angles to PS, the vibration plane of the incident ligh

FIG. 362.

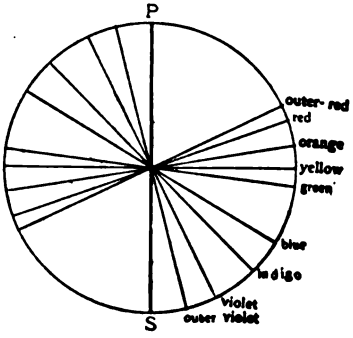


FIG. 363.

With Convergent Light and Crossed Nicols.

In sections normal to the optic axis with monochromatic light sections not too thin will show the dark cross with arms parallel t the vibration planes of the nicols. The arms will be either indis tinct near the center, or in thicker sections will not reach th center, Fig. 363. The first ring will be some distance out, beyon this there will appear the alternate dark and light rings.

With white light the central circle will have the color tint whic is obtained over the entire field when parallel light is used.

The Direction of Rotation may be ascertained in convergent ligh by :

(a) *The widening of the arcs* when the analyzer is turned in th direction of rotation.

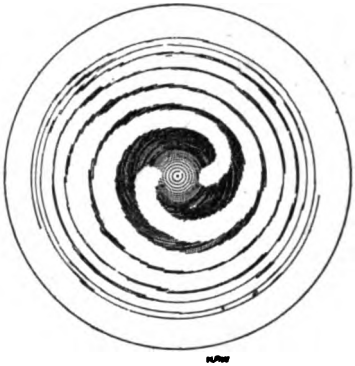
(b) *A quarter undulation mica plate* inserted diagonally abov the plate converts the rings and cross into two interwound spirals which start near the center and wind in the direction of rotation,*

* A plate of left and another of right-handed substance give a fourfold spiral i which the direction of winding conforms to the lower plate.

. 364, Right; Fig. 365 Left. If the mica is placed below the e the spirals are reversed.

FIG. 364.

FIG. 365.



OPTICALLY BIAXIAL CRYSTALS.

THORHOMBIC, MONOCLINIC AND TRICLINIC CRYSTALS.

n orthorhombic, monoclinic or triclinic crystals by measure- nt of the indices of refraction with light of any definite wave- gth (monochromatic light), two directions of single refraction found, and these directions, from analogy with the uniaxial, called the "Optic axes" *for light of that wave-length.* In all er directions there is double refraction and the directions of optic axes are not the same when light of a different color is d.

tical Principal Sections and Principal Vibration Directions.

f, with any one light, the indices of refraction are determined all directions, the resultant values are found to always be sym- trical to three planes at right angles to each other which inter- t in the vibration directions of the fastest and slowest rays, the rd intersection being the vibration direction of a ray of some ermediate velocity.

These planes of symmetry are called *Optical principal sections* l their intersections are called *Principal vibration directions*, and y be designated by a, b and c, in which a is the *vibration* direc- n of the fastest transmitted ray, c the *vibration* direction of the west transmitted ray, b the *vibration* direction of the ray trans-

mitted at right angles to the other two rays and with some inte mediate velocity.

Principal Indices of Refraction.

The directions of vibration are at right agles to the direction transmission. The indices of refraction of the three rays wi vibration directions $\mathfrak{a}$, $\mathfrak{b}$, $\mathfrak{c}$, are denoted by α, β and γ, and call the principal indices of refraction. Then evidently $\alpha < \beta <$ and also there will be transmitted in the direction $\mathfrak{a}$ two ra with vibration directions $\mathfrak{b}$ and $\mathfrak{c}$ and indices of refraction β and

Similarly in the direction $\mathfrak{b}$ there will be transmitted two ra with vibration directions $\mathfrak{a}$ and $\mathfrak{c}$ and indices α and γ; and in t direction of $\mathfrak{c}$, two rays with vibration directions $\mathfrak{b}$ and $\mathfrak{a}$ and i dices β and α.

Optically Positive and Negative Crystals.

The optic axes or directions of single refraction lie always in t plane of $\mathfrak{a}\,\mathfrak{c}$. According to the angle which they make with $\mathfrak{a}$ a $\mathfrak{c}$ the following division is made:

If $\mathfrak{c}$ bisects the *acute* angle between the optic axes the crystal said to be optically *positive*. This is usually expressed: +, $Bx_a =$

If $\mathfrak{a}$ bisects the *acute* angle between the optic axes the crystal said to be optically *negative*. This is expressed: —, $Bx_a = \mathfrak{a}$.

Measurement of the Principal Indices of Refraction.

The Prism Method.

In biaxial crystals the direction of transmission for minimu deviation will yield a principal index of refraction, only when it normal to one of the directions $\mathfrak{a}$, $\mathfrak{b}$ or $\mathfrak{c}$, and at least two different oriented prisms will be necessary to secure the three princi indices.

By the total reflection* method all three indices can be obtain from any plane surface parallel to any one of $\mathfrak{a}$, $\mathfrak{b}$ or $\mathfrak{c}$.

INTERFERENCE PHENOMENA BETWEEN CROSSED NICOI WITH PARALLEL POLARIZED LIGHT.

In sections normal to an optic axis no extinction will take plac but with monochromatic light the field will maintain a unifor brightness during rotation of the stage and with white light the may be even a color tint.

* A. J. Moses, *Character of Crystals*, p. 146.

n all other sections the field is dark every 90° and is illuminated
ll other positions and most brilliantly in the diagonal positions.
hite light is used interference colors result as described, p. 161.

inction Directions.

he Extinction Directions are determined as described, p. 166.
also under distinctions between orthorhombic, monoclinic
triclinic, p. 176.

erference Colors.

he Interference colors with white light are essentially as de-
ed, p. 161, though with marked "divergence" they are modi-
by color tints due to the partial or complete extinction of
ain colors.

he other determinations with parallel light are exactly as de-
ed under uniaxial crystals.

erference Phenomena Between Crossed Nicols with Convergent Polarized Light.

n sections cut normal to either a *or* c, *that is normal to a* BISECTRIX *he angle between the optic axes, with monochromatic light*

interference figure results, the field being dark throughout
entire revolution for all points at which $\frac{\Delta}{\lambda} = 1, 2, 3$, etc., p. 161,
brightest for $\frac{\Delta}{\lambda} = \frac{1}{2}, \frac{3}{2}, \frac{5}{2}$, etc. The points of emergency of

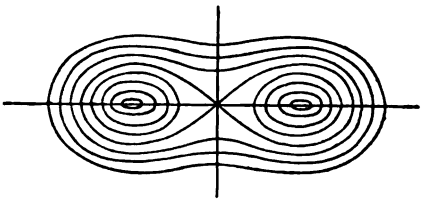


FIG. 366.

optic axes will therefore be dark, since $\frac{\Delta}{\lambda} = 0$, and the points
responding to $\frac{\Delta}{\lambda} = 1$ will together form a ring around each axis
similarly for values of 2, 3, 4, etc., until the pair corresponding
st nearly to the value $\frac{\Delta}{\lambda}$ for the centre of the field unite at or
ar the centre to a cross loop or figure eight around both axes and

subsequent rings form lemniscates around this as in Fig. 366. Th
will be no change in shape during rotation of the stage. If $\frac{\Delta}{\lambda}$
the centre is less than unity even the first ring must surround b
axes.

With sections of the same mineral the thicker the section
closer together will be the rings, and with sections of different m
erals but equal thickness the grea
the difference between α and γ
closer together the rings.

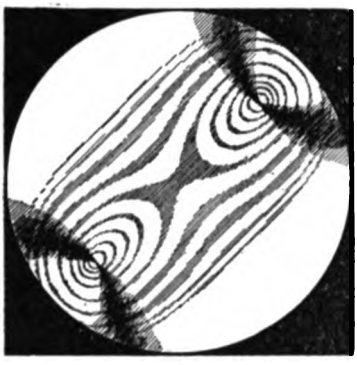


FIG. 367.

Corresponding to the dark cr
p. 167, and due to the same ca
there will be a sharp dark ba
joining the axes and another son
what thicker lighter band at ri
angles to the first and midway
tween the axes, but they differ fr
the uniaxial cross in that as
stage is rotated the straight b
change into a hyperbola, Fig. 3
the branches of which rotate in
opposite direction to the stage, the convex side always toward
other branch.

With white light the light and dark rings are replaced by int
ference colors.

Determination of Optical Character of a Crystal.

In a section *normal to the acute bisectrix** the interference f
ure is placed with the line joining the axial points in diagon
position, as in Fig. 367, and the quartz wedge is gradually
serted with the direction c parallel to this line. If the crystal
positive the rings around each axis will *expand*, moving toward t
centre and corresponding rings will merge in one curve.

If the crystal is *negative* the rings will *contract* and increase
number, the change increasing with the thickness of wedge int
posed. In a section *normal to the obtuse bisectrix* these resu
are all reversed.

* To determine the acute bisectrix it may be necessary to first measure the a
angle. Ordinarily the interference figure in a section normal to the obtuse bisectrix w
not come within the limits of the field.

n crystals with a small axial angle the mica or gypsum plate y be used as described, p. 167.

termination of the Angle Between the Optic Axes.

A section cut normal to the acute bisectrix is held at *P*, Fig. 3, between the lenses of a horizontal polariscope. The vibration ections of the nicols of the polariscope are crossed at 45° to horizon, so that when the line connecting the axial points is izontal the interference figure will show the hyperbola and not cross. The section must be centred so that a line in it is the s of revolution; and so that the axial points of the interference ire remain on the horizontal cross hair during revolution.

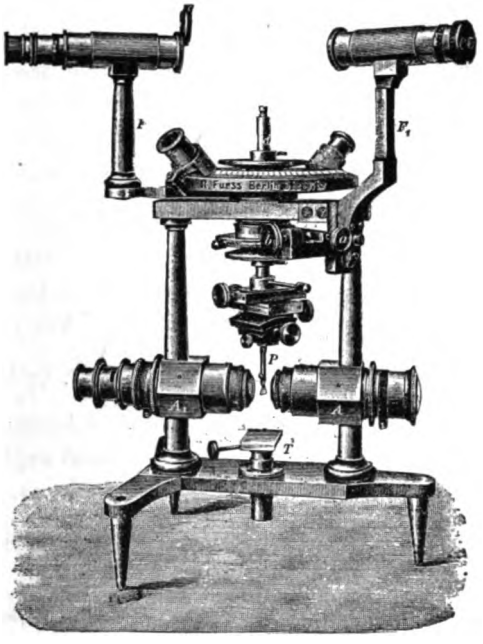


FIG. 368.

The crystal is then revolved by the horizontal plate until the o arms of the interference hyperbola are successively made ngent to the vertical cross-hair, the positions being read on the ate. The difference between the two readings is the apparent gle $2E$, and this is frequently the angle recorded. It is always ger than the true angle $2V$.

Fig. 368 shows the newer type of so called Universal Apparat of Fuess. The centring device is precisely that described under th Fuess goniometer and may be inserted either as in the figure or i verted. In the latter position it forms with the telescopes F_1 a F the equivalent of the Fuess goniometer, Fig. 273.

When used for axial measurements, the crystal stand is replac by the pincers P which clip the crystal plate. The optical po tion inserted at A and A_1 is the same Norremberg arrangement nicols and lenses which is shown in Fig. 357, but turned so th the vibration directions of the nicols cross at 45° to the horizo

To find the True Angle from the Apparent Angle.

When the middle principal index β is known $2V$ may be dete mined by the relation $\sin V = \frac{\sin E}{\beta}$.

When β is not known a second measurement may be made the apparent angle in a plate normal to the *obtuse* bisectix. D noting this by $2E'$ the relation is $\tan V = \frac{\sin E}{\sin E'}$.

Approximate Measurement of the Axial Angle.

The axial angle $2V$ may be determined in any suitably equipp microscope or polariscope by measuring the distance d from th centre to either hyperbola, or the average of the two distance with a micrometer eye-piece. Then $\sin E = \frac{d}{C}$, or $\sin V = \frac{d}{\beta C}$, which C is a constant for the same system of lenses and is dete mined once for all with a crystal of known axial angle.

For instance if in a mica $2E = 91° 50'$ and $d = 41.5$ divisions the scale, then $C = \frac{d}{\sin E} = 57.55$ for that combination of lenses

OPTICAL DISTINCTIONS BETWEEN ORTHORHOMBIC, MONO CLINIC AND TRICLINIC CRYSTALS.

In *Orthorhombic Crystals* the crystallographic axes are alway principal vibration directions and the axial planes are optical pri cipal sections for all colors.

It is therefore possible to recognize the system of an orthorhon bic crystal by:

(*a*) *The extinction directions* which will always be parallel symmetrical to crystallographic edges, cleavage cracks, etc. I

nacoidal faces the vibration direction will be parallel to the crystal es.

(*b*) *The interference figure* obtained in sections parallel *to two of three pinacoids* will be like Fig. 367, and if the figures so obtained e viewed in white light the color distribution will be symmetrical *h* to the line joining the optic axes and to the line through the ntre at right angles thereto.

In Monoclinic Crystals the ortho axis $\bar{b}$ is always a principal vi-ation direction and the clinopinacoid is an optical principal sec-n for all colors, the other two principal vibration directions lie in e clinopinacoid, but vary in position with the wave-length.

It is therefore possible to recognize the system of a monoclinic ystal by:

(*a*) The extinction directions which are parallel or symmetrical edges, cleavages, etc., *only when* the section is parallel to the tho axis *b*, but in all other zones are oblique.

(*b*) The *interference figure* similar to Fig. 367 will be found either the section parallel to the clino pinacoid or in one of two sec-ns normal to this. In *white light* the distribution of color of s figure will never be symmetrical to *two* lines as in the ortho-ombic, but will be symmetrical either to the line joining the ial points, or to the line normal to these, or to the central point.

In *triclinic crystals* there is no essential relation between crys-lographic axes and principal vibration directions, all extinctions e oblique and in white light, the distribution of color in the in-ference figure is entirely without symmetry.

ABSORPTION AND PLEOCHROISM.

Light during transmission through a crystal is in part absorbed d in most instances diminishes steadily in intensity as the dis-nce traversed increases.

With white light the different component colors are absorbed at ferent rates, giving color tints due to the combination of the maining colors.

Isometric Crystals.

A section of any given thickness will transmit the same color t whatever the direction in which the crystal may be cut.

In Doubly Refracting Crystals.

In all doubly refracting crystals the ordinary and extraordina rays transmitted in any given direction may be differently absorb and with white light the color tints may be different; not only the ordinary and extraordinary rays transmitted in one directi but also for different directions.

Usually the ordinary and extraordinary rays may be view separately by means of a polarizing microscope with the analy out. The color varies as the stage is turned and the maximu color differences are obtained when the extinction directions co cide with the vibration plane of the polarizer.

The colors of the ordinary and extraordinary rays may be *c trasted* side by side by means of a "dichroscope" consisting, Fig. 3

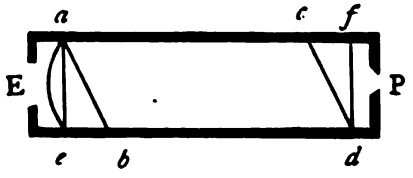


FIG. 369.

of a rhomb of calcite in which *ab* and *cd* are the short diagonals opposite faces. To these faces glass wedges *aeb*, *dfc* are cement and the whole encased. The section is placed at *P* and the lig from the substance passes through a rectangular orifice, a doub image of which is seen by the eye at *E*.

In Tetragonal and Hexagonal Crystals with the Polarizi Microscope.

In sections normal to the opic axis the color is constant for positions of the stage.

In sections parallel to the opic axis. If the extinction directi parallel to the optic axis is placed first parallel then at right angl to the short diagonal of the polarizer there will be seen first t extraordinary, second the ordinary.

In all other sections the extraordinary will be found to approa the constant tint of the ordinary as the sections become mo nearly perpendicular to the optic axis.

Optically Biaxial Crystals:

n orthorhombic crystals the directions of the absorption axes ıcide *for all colors* with the directions of crystal axes and the cipal vibration directions a, b and c.

n monoclinic crystals one absorption axis is parallel to the crystal $\bar{b}$, therefore to one of a, b or c, the other axes lie in the opinacoid, but, for any color, may or may not coincide with a ıd c for that color.

n triclinic crystals no coincidence is essential.

Although subject to many exceptions, the law of Babinet is erally correct that "the slower transmitted ray is the more ab-ed."

CHAPTER XVIII.

THE THERMAL, MAGNETIC AND ELECTRICA CHARACTERS.

THE THERMAL CHARACTERS.

Transmission of Heat Rays.

HEAT rays are subject to the same laws as light rays and di principally in their greater wave length. They may be reflect refracted, doubly refracted, polarized and absorbed. It is possib though difficult, to determine experimentally a series of consta for crystals with respect to these invisible rays, but their discussi belongs rather to physics than to mineralogy.

Surface Conductivity.

The relative surface conductivies may be obtained when previously cleaned and polished section is breathed upon, quic touched by a very hot metal point normally applied, and instan dusted with lycopodium powder. The section is then turned side down and tapped carefully, when the powder falls from wh the moisture film had been evaporated, but adheres elsewhe giving a sharply outlined figure. The entire operation should t less than three seconds.

Or the section may be coated with a mixture of three pa elaidic acid and one part wax, and brought into contact wit heated metal point, and a constant temperature maintained u the wax has melted far enough from the point of application of heat. The boundary of the melted patch then shows the distan which the heat has been transmitted, and is visible after cooling a ridge which is always an ellipse or circle.

In singly refracting crystals (*isometric*) all sections yield circ

In optically unaxial crystals (*tetragonal or hexagonal*) basal s tions yield circles, but all other sections yield ellipses which come more eccentric as the section becomes more nearly para to the optic axis.

In optically biaxial crystals the curves are all ellipses. orthorhombic crystals the axes of the ellipse obtained in any a

ne are parallel to the crystal axes therein. In monoclinic crys- the major and minor axes of the isothermal curves should ncide with crystal axes in any plane parallel to $\bar{b}$. In triclinic stals there will be no essential or probable paralellism of crystal s and axes of ellipses in any section.

pansion.

When a crystal is uniformly heated, directions crystallographic- alike expand in the same proportion, but directions unlike not.

1° *Isometric Crystals.* The rate of expansion is the same for all ections.

2° *Tetragonal and Hexagonal Crystals.* The rate of expansion he same for all directions equally inclined to the axis c; is either naximum or a minimum parallel to c, and varies regularly from s to directions at right angles.

3° *Orthorhombic Monoclinic and Triclinic Crystals.* The direc- ns of maximum and minimum expansion are at right angles. Orthorhombic, the direction coincides with two of the crystal es.

Monoclinic, one direction may coincide with $\bar{b}$, or both lie in the no pinacoid.

Triclinic, the axes have no fixed positions relative to crystal.

The increase in expansion may be accurately measured for any ection by the method of Fizeau, as follows:

In Fig. 370 O is a plane parallel te of the crystal, about 10 mm. ck, which rests upon the steel plate Three screws pass through T and pport the glass plate P, which tapers ghtly. By adjusting the screws so t the upper surface is horizontal thin wedge-like film of air is left ween the upper surface of the sub- nce and the lower surface of the ss.

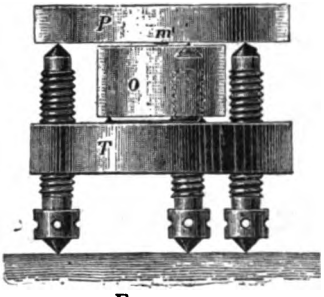


FIG. 370.

By a suitable arrangement, rays of monochromatic light strike apparatus normally. Rays incident at the upper surface of the stal and the lower surface of the glass wedge interfere on reflec- n producing parallel dark bands wherever the thickness of the dge is $\frac{1}{2}\lambda$, $\frac{3}{2}\lambda$. The distance between two adjacent bands is

therefore a function of a wave-length of the light used and is m
ured by a screw micrometer.

When the apparatus is uniformly heated the crystal plate
the interference apparatus both expand and the interference ba
change in distance apart. From this change and from the
viously determined effect of the expansion of the metal stand
change due to the expansion of the crystal is calculated.

Tutton has recently described an improvement of this appara
in which the expansion of the metal stand is compensated by
of a cylinder of aluminum.

Change of Crystal Angles produced by Expansion.

A crystal of the isometric system when uniformly heated
pands uniformly without change of angles. In all other syst
the expansion varies with the direction and certain angles
changed (sometimes several minutes for 100° temperature alt
tion. For instance, the calcite rhombohedron angle is lesse
8′ 37″.) The zone relations and indices are never changed.

These changes may be measured with accurate goniometers
the relative expansions calculated.

Change of Optical Characters produced by Expansion.

The expansion of a crystal changes the velocity of light tra
mission and therefore the indices of refraction for different directi
With isometric crystals the index may become either larger
smaller. With tetragonal and hexagonal crystals the princi
indices of refraction γ and α may alter unequally and not ne
sarily in the same direction. The interference figure will also a
the rings contracting or expanding according to the change in γ
and for a particular temperat
when this difference is zero, will
appear.

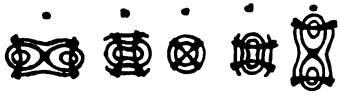


FIG. 371.

In orthorhombic, monoclinic
triclinic crystals the interference
ure may undergo even more strik
changes. For instance, Fig. 371 represents such a series in
gypsum with yellow light for which at 20° C. the axial angle is
(Fig. *a*), at 100° C. is reduced to 51° (Fig. *b*), at 134° C. is
(Fig. *c*), and for still higher temperatures the optic axes pass in
plane at right angles to their former position (Figs. *d* and *e*).

THE MAGNETIC CHARACTERS.

Only a few minerals noticeably disturb a magnetic needle or are tracted by a steel magnet. Occasionally these minerals will themlves act as magnets.

ara- and Diamagnetism.

All substances are either attracted or repelled in some degree the field of a strong electromagnet. If attracted they are said be "*paramagnetic*" or "*magnetic*"; if repelled they are "*diagnetic.*"

If a rod of any substance is suspended by a fiber so as to swing ely horizontally between the vertical poles of an electromagnet, e rod, if paramagnetic, is pulled into "*axial*" position with its ds as near the poles of the magnet as possible, and, if diamagtic, is pushed into an "*equatorial*" position with its ends as far om the magnetic poles as possible.

Crystals are more strongly magnetized in certain directions than others, and the para- or diamagnetism is judged by hanging a in glass tube, filled with powder of the substance, between the agnetic poles, the particles of the powder, having all possible ientations, eliminate all effect of direction.

elative Induction in Different Directions in a Crystal.

The para- or diamagnetism is determined as described. A cube the crystal is then suspended by a silk fibre between the poles of electromagnet and with its three rectangular axes successively rtical. If, for instance, in a diamagnetic substance for the three spensions, one of the axes twice assumes the *equatorial* position, en this is the direction of greatest magnetization, but if the subance is paramagnetic the axis which twice assumes an *axial* posion is the direction of greatest magnetization.

The relations cannot yet be said to be well understood as very w minerals have been thoroughly tested.

ELECTRICAL CHARACTERS.

rictional Electricity.

All minerals are electrified by friction but the positive or negative haracter may vary in different varieties of the same species and ven with different conditions in the same specimen.

If a light, horizontally-balanced needle terminating in small balls electrified, either positively by bringing near a rod of electrified

sealing wax, or negatively by touching with the rod, an electrifie mineral will attract or repel the needle according as it has opposit or similar electricity.

Electrical Conductivity.

If a prism of known dimensions is introduced into a direct weal current, the strength of which is varied by resistances and th deviation observed in a galvanometer, results will be obtaine which vary for different minerals between very wide limits an appear to be dependent upon the constitution of the chemica molecule rather than upon the crystalline structure. A certai dependence upon crystallographic direction has nevertheless, bee observed in a few substances.*

All minerals conduct to some extent, but practically, conductivit may be considered to be limited to the metals; some metalloids most sulphides, tellurides, selenides, bismuthides, arsenides and an timonides, some of the oxides; and, at higher temperature, a fe haloids.

Thermo-electricity.

If a metallic circuit is made by soldering together one end o each of two rods of different metals and connecting the other end by wire, heating or cooling the junction will develop an electri current the strength of which will depend upon the change o temperature and upon the metals used.

A series may be made based upon the strength and direction o the current. Among metals the series extends from bismuth a the positive end to selenium at the negative end. The position o minerals in the series may be practically determined.

In crystals, moreover, a thermo-electric current is developed b coupling two rods cut from different directions in the same crystal or by inserting a single rod in a metallic circuit and either heatin the ends while the sides are kept at a uniform temperature or b the reverse proceeding.

Dielectric Induction.

A crystal suspended in an electrostatic field develops an electri polarity, and the crystal tends to assume a position in which th lines of force and the direction of maximum induction are parallel

* Uber das Leitungsvermögen der Mineralien für Elektricität. F. Beijerinck, *Neue Jahrb. Min.*, Beil, Bd. XI., 403, 1896–7. Also Wortman, Mem. de la Soc. d. hist Nat. de Genève, XII., 1853.

In the experiments of Root * circular plates of tourmaline, artz, calcite, aragonite and topaz about 10–11 mm. in diameter d cut parallel to the optic axis, were attached by a little drop of e to a silk fibre and suspended between the vertical plates of ondenser charged by a rapidly alternating current. The vibra- n thereby produced in the plate was reflected to a telescope two ters distant, and its period determined both when the direction maximum induction was vertical and horizontal. The quotient the former by the latter gave a basis of comparison.

roelectricity and Piezoelectricity.

Whenever the volume of a crystal is altered either by a tempera- e change or by mechanical pressure a portion of the heat ergy or mechanical energy may be converted into electric en- y, which, in poorly conducting crystals, will be frequently mani- ed by the accumulation of positive and negative charges at erent points or poles.

In PYROELECTRICITY a temperature change of at least 70° to 80° is desirable. Usually the crystal is heated† in an air bath to a form temperature, then drawn quickly once or twice through alcohol flame and allowed to cool.

During the cooling of the crystal the positive charges collect at so-called *antilogue* poles, and the negative charges at the *ana- ue* poles,‡ and may be distinguished by their effect on other ctrified bodies. For instance, a cat's hair rubbed between the gers becomes positively electrified and is attracted by the analo- us pole and repelled by the antilogous pole.

Or the positive and negative poles may be distinguished by owing upon the cooling crystal a fine well dried § mixture of ual parts of powdered sulphur and red oxide of lead. The noz- of the bellows is covered by a muslin net and in the passage ough the sulphur is negatively electrified and is attracted by the sitive poles coloring them yellow while the minium is posi- ely electrified and is caught by the negative poles coloring them l. The dust should fall evenly and the bellows be held far ough away to prevent direct action of the blast.

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* *Poggendorf's Annalen*, CLVIII., 1, 425, 1876.

† If heating injures the crystal it may be cooled from room temperature by a freezing ture.

‡ With rising temperature these are reversed.

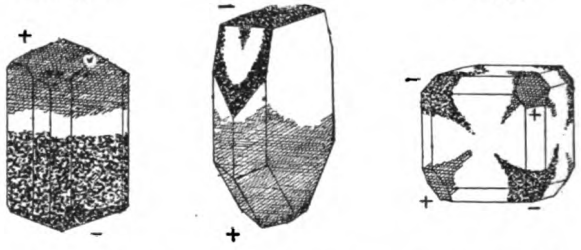
§ Dry over H_2SO_4 in a vessel from which the air has been partially exhausted.

Figs. 372, 373 and 374 show crystal of tourmaline, calamin and boracite respectively, the darker dotted portions represen ing the accumulation of minium at the analogue poles and th hatched portions the accumulations of sulphur at the antilogu poles.

If the crystals had been dusted during the heating, the analogu poles would have been coated with sulphur and the antilogue pole with minium.

In PIEZOELECTRICITY the charges are developed by pressure, fo instance, calcite pressed between the fingers becomes positivel

FIG. 372. FIG. 373. FIG. 374.



electrified, tourmaline compressed in the direction of the vertica axis develops a positive charge at the antilogue end and a nega tive charge at the analogue end or precisely the charges whic would result from cooling a heated crystal.

The charges are detected in the same way as the pyroelectri charges.

CHAPTER XIX.

CHEMICAL COMPOSITION AND REACTIONS.

As has already been stated, minerals are distinguished from ocks by something of regularity in their chemical structure. While all minerals may be best considered as derived from definite hemical types they are, however, very far from being of definite nd invariable composition and it is often difficult to represent the esults of analysis by an exact formula. This is readily under-tood when the laws of isomorphism and the conditions underly-ng the formation of minerals are studied.

Isomorphism.

Certain chemical substances, having an equal number of atoms n their molecules and presenting a close resemblance in their re-ctions, crystallize in forms which are either identical or very losely related. Such isomorphic substances cannot be separated rom each other by ordinary crystallization as the analogous com-ounds crystallize together, and the crystals formed show by analy-is the most varied quantitative proportions of the isomorphic sub-tances present in the liquid.

Most minerals are isomorphic mixtures. They have, as a rule, een formed by crystallization either from solution or from fusion. Some, as limonite, have been formed by a process of sedimentation ut such are uncrystallized, and are generally quite impure. Others re the results of alteration from atmospheric agencies and fre-uently contain in the same specimen the original mineral and s alteration product.

Whenever a mineral has crystallized from solution or from fu-ion it is always more or less modified by the elements which may e present and which are foreign to its own typical structure. Three cases present themselves :

1. If the liquid contains no other substance than the compound f which the mineral is made then it crystallizes out in a state of urity and is as definite in its composition as any compound made n the laboratory.

2. If the liquid contains several other substances but none whic is isomorphous with the compound of which the mineral is made, i may crystallize in all degrees of purity, tending always to forn crystals of definite composition but the composition of the mas varying with the degree with which the liquid is saturated wit the foreign substances. This gives rise usually to a series of frac tional crystallizations especially apparent in beds of rock salt or i mica and orthoclase veins. If the substances are in solution tha one is first deposited whose saturation point is first reached by an process of concentration, the others following in their respectiv order. Where the case is one of fusion those substances with th highest melting points will tend to crystallize out first and in state of comparative purity.

3. The liquid may contain two or more isomorphic compound in which case the resulting mineral will contain each of these sub stances usually in about the relative proportion in which they wer present. Isomorphic compounds are generally salts of the sam acids with the metallic elements different.

Composition and Formula.

It will thus be seen that many factors besides the results of analy sis must be taken into consideration in giving a formula to an mineral. When, however, the errors of calculation, arising fron the impurities and from the replacing of certain elements by other of different atomic weight but isomorphous with them, are elimi nated, it is generally possible to assign a typical formula to th species. The difficulty becomes greater when the polysilicates an some other complicated minerals are studied and in no case mus the formula for the species be considered as absolutely invariabl for the individual. The results of alteration through atmospheri agencies, infiltration of water, etc., tend at times to so alter th individual that its composition varies widely from the type while a times this alteration is carried on so regularly and so far that ne species of quite definite composition are formed. In expressin the composition by formulas the ordinary chemical symbols ar used. The letter R is used to represent a varying group of iso morphic or equivalent elements, and it may have the valency o these elements designated by dots above and to the right of th letter. When two elements as (Fe.Mg) are placed in parenthesi

ith a period between it, indicates that the two replace each other all proportions in the different individuals of the species.

Types.

The most prominent types found among minerals are as follows:

1. The ELEMENTS, as Au, Ag, Cu, Sb, C, S. These are frequently alloyed with other elements as copper with silver, sulphur ith selenium, etc.

2. The OXIDES and HYDROXIDES for which water, H_2O, serves as type, as cuprite, Cu_2O, brucite, $Mg(OH)_2$. It is not necessary at the hydrogen atom or atoms be replaced by a single element. his replacement may be by a group of elements as in diaspore, lO(OH) or on the other hand the oxygen may be partially replaced by sulphur as in kermesite, Sb_2S_2O.

3. The SULPHIDES, derivatives of H_2S, and to a less extent their nalogues the SELENIDES, TELLURIDES, ARSENIDES and ANTIMONIDES, galenite, PbS, clausthalite, PbSe, hessite, Ag_2Te, niccolite, NiAs. he hydrogen may be replaced by more than one element as in nalcopyrite, $CuFeS_2$, or the sulphur may be partially replaced by rsenic as in arsenopyrite, FeAsS, by antimony as in stephanite, g_5SbS_4 and also by selenium and by tellurium, but to a less extent nd with smaller tendency to form distinct species.

4. The CHLORIDES, derivatives of HCl, and to a less extent their nalogues the FLUORIDES, BROMIDES, and IODIDES as halite, NaCl, uorite, CaF_2, bromyrite, AgBr, iodyrite, AgI.

More than one metal may replace the hydrogen as in the double uoride cryolite, Na_3AlF_6, and chlorides, bromides, iodides or uorides may crystallize together as in embolite, Ag(Cl.Br).

5. NITRATES, derivatives of HNO_3, as nitre, KNO_3; soda nitre, aNO_3; isomorphic or basic modifications are rare.

6. CARBONATES, derivatives of H_2CO_3, as calcite, $CaCO_3$; siderite, $FeCO_3$, etc. Isomorphic combinations are common, as dolomite (Ca. Mg)CO_3. The carbonates of Zn, Fe, Co, Mn, Ca and Mg re isomorphous, and also the carbonates of Ca, Ba, Sr and Pb. Consequently, minerals containing various combinations of these arbonates are found. Many basic salts of carbonic acid also ccur, as malachite, $Cu_2(OH)_2CO_3$; azurite, $Cu_2(OH)_2(CO_3)_2$. Carbonates are also frequently found containing water of crystallization as natron, $Na_2CO_3 + 10H_2O$. In a few instances a carbonate nd a halogen salt crystallize together as in phosgenite, $Pb_2Cl_2CO_3$,

7. SULPHATES, derivatives of H_2SO_4, as anhydrite, $CaSO_4$; barite $BaSO_4$, etc. Isomorphic combinations are more common than simple sulphates. Among these may be noted sulphates containing two or more metals, as glauberite, $Na_2Ca(SO_4)_2$; those containing sulphate and chloride, as kainite, $MgSO_4.KCl + 3H_2O$. Basic sulphates are also numerous as brochantite, $Cu_2(OH)_2SO_4.2\,Cu(OH)$ and some individuals of any of the previous types crystallize with water of crystallization, as copiapite, $Fe_2(FeOH)_2(SO_4)_5 + 18H_2O$.

8. CHROMATES, derivatives of H_2CrO_4, as crocoite, $PbCrO_4$, and derivatives of $HCrO_2$, as chromite, $FeCr_2O_4$. These are the two important mineral chromates. Two or three rare basic compounds are also known.

9. MOLYBDATES, derivatives of H_2MoO_4, as Wulfenite, $PbMoO_4$, which is the only important natural molybdate.

10. TUNGSTATES, derivatives of H_2WO_4, as scheelite, $CaWO_4$. Tungstates also are rare. One or two isomorphic combinations are known, as in Wolframite, $(Fe.Mn)WO_4$.

11. BORATES, derivatives of HBO_2, H_3BO_3 or of $H_2B_4O_7$, as sassolite, H_3BO_3; borax, $Na_2B_4O_7 + 10H_2O$. Metaborates are rare. Ulexite, $CaNaB_5O_9 + 6H_2O$, may be considered as a molecular combination of $CaB_4O_7 + NaBO_2$, while colemanite, $Ca_2B_6O_{11} + 5H_2O$, would consist of $CaB_4O_7 + Ca(BO_2)_2$. Most natural borates contain water of crystallization, and a few basic combinations are found.

12. ALUMINATES, derivatives of $HAlO_2$, as spinel, $Mg(AlO_2)_2$, chrysoberyl, $Gl(AlO_2)_2$. The aluminates are isomorphous with the ferrates and metachromates, consequently the Al may be partially replaced by Fe or Cr, while, on the other hand, the common aluminates are themselves isomorphous, and the Mg, Fe, Zn and Mn salts replace each other in their characteristic spinels to a limited extent.

13. PHOSPHATES, derivatives of H_3PO_4, as vivianite, $Fe_3(PO_4)_2 + 8H_2O$. By far the majority of mineral species of phosphates are either isomorphic modifications or basic salts, both with and without water of crystallization. Simple phosphates may crystallize together, as in triphylite, $Li(Fe.Mn)PO_4$. Phosphates may crystallize with chlorides and fluorides, as in apatite, $Ca_5(Cl.F)(PO_4)_3$. Basic salts may be simple, as in turquois, $Al_2(OH)_3PO_4 + H_2O$, or may contain several metals, as in lazulite, $(Mg.Fe.Ca)Al_2(OH)_2(PO_4)_2$.

4. ARSENATES, derivatives of H_3AsO_4, form compounds very iiar to the phosphates in molecular structure, as scorodite, $AsO_4 + 2H_2O$, a hydrous ferric arsenate; mimetite, $3Pb_3(AsO_4)_2$ $PbCl_2$, a combination of the isomorphic arsenate and chloride; enite, $Cu_2(OH)AsO_4$, a basic copper arsenate.

5. VANADINATES and COLUMBATES, derivatives of H_3VO_4 and bO_3. The chief vanadinates are vanadinite, $3Pb_3(VO_4)_2 + PbCl_2$, olecular combination of lead vanadinate and chloride, and cloizite (Pb.Zn) $(Pb.OH)VO_4$, a basic lead vanadinate contain- zinc. The most important natural columbate is the mineral umbite, $Fe(CbO_3)_2$.

6. SILICATES.—By far the largest number of minerals known under this subdivision. Isomorphic combinations are the e, and these combinations are at times so complicated that it is ost impossible to give even a typical formula to the species. sic and acidic salts are common, but the silicates do not show great tendency to crystallize with water of crystallization as is sessed by some of the other classes of compounds. Those ich do contain water of crystallization are commonly considered a class by themselves, on account of their many resemblances. e basic elements most commonly replacing each other are Mg, Fe, Zn and Mn; Na, Li and K, and Al, B, Cr and Fe. e silicon is itself sometimes partially replaced by Al, as in rthite, or by Ti, as in titanite.

Calculation of Formulas.

n expressing the composition of a mineral by a formula we e only the atomic weights of its component elements and results of analysis from which to calculate. Hence the nulas given do not of necessity express the structure of the lecule, but only the composition ratio. In fact, the symbols pted are always the simplest which can express the propor- ns shown by analysis to exist between the atoms and which sfy their valences. The true molecular formulas are proba- always some unknown multiple of these symbols. For the poses of mineralogy, however, the composition formulas are ficient.

An example may make this point clearer. A very pure speci- n of beryl gave the following results on analysis:

	Per cent.
GlO, ...	14.01
Al_2O_3, ...	19.26
SiO_2, ...	66.37

The sum of the atomic weights for each group is:

$$GlO = 25.$$
$$Al_2O_3 = 102.$$
$$SiO_2 = 60.$$

The results of analysis represent the proportion in which t groups are present in the molecule. Consequently, the relati between the number of groups must be:

Percentage Composition.		Atomic Weights.		Proportionate Number of Groups.
14.01	÷	25	=	.56
19.26	÷	102	=	.189
66.37	÷	60	=	1.106

Now, as fractional atoms cannot exist, our problem is simply find the smallest number of whole groups which stand to ea other in this relation, and, as .56 : .189 : 1.106 = 3 : 1 : 6, ve nearly, therefore, the composition is represented by $3GlO + Al_2$ $+ 6SiO_2$, which may be better written $Gl_3Al_2Si_6O_{18}$, or, as it at on becomes evident that the proportion between silicon and oxyg is that of a metasilicate, $Gl_3Al_2(SiO_3)_6$.

It will now be found, on calculating the theoretical percenta composition of $Gl_3Al_2(SiO_3)_6$, that it agrees within the limits error with that found by analysis, and as the twelve affinities the six SiO_3 radicals are satisfied by those of Gl and Al atoms, t formula probably represents the composition of the compour The true molecular formula is, however, $nGl_3Al_2(SiO_3)_6$ wherein represents some whole number.

The calculation is not generally as simple as the above examp might indicate. Usually, minerals contain elements which see foreign to their true composition, and which are present either impurities or which replace analogous elements of the true mol cule. In fact, many beryls contain Cs, H_2, Na_2, Ca, or Mg repla ing Gl; and Fe or Cr replacing Al. Such replacing elements, present only in small quantities, must be converted into their equi

lents of Gl or Al before the calculation for formula is made. lo representative formula can ever be assigned from an analysis f impure material unless the nature and extent of the impurities re known.

Clues are often obtained as to the constitution of the molecule hich are entirely foreign to the percentage composition, but which aterially assist in the construction of the formula. Thus H_2O, resent as water of crystallization, is driven off at comparatively w temperatures, while the hydrogen of hydroxides or of acid or asic salts is usually expelled as water only under a temperature proaching that of ignition. Orthosilicates are known to be much ss stable than metasilicates, and frequently are found altered to etasilicates. This fact sometimes aids in determining the for- ula of a compound which otherwise might be referred to either ass. For instance, analytical results have been obtained for both ndalusite and cyanite, which are satisfied by the formula Al_2SiO_5. his represents more oxygen than is present in any of the silicic ids, and part of the oxygen is therefore undoubtedly in com- nation with the aluminium. Two rational formulas now become ossible, one an orthosilicate $Al(AlO)SiO_4$, the other a metasilicate $AlO)_2SiO_3$. Andalusite is much more easily decomposable than yanite, which is not so easily altered. The first symbol is there- re assigned to andalusite and the second to cyanite.

CHAPTER XX.

THE IRON MINERALS.

The minerals described are: *Metal*—IRON. *Sulphides a arsenides*—PYRRHOTITE, PYRITE, MARCASITE, ARSENOPYRITE, LEUC PYRITE. *Oxides*—MAGNETITE, FRANKLINITE, HEMATITE, MENACCA ITE, TURGITE, GOETHITE, LIMONITE. *Sulphates*—COPIAPITE, MELA TERITE. *Phosphates*—VIVIANITE, TRIPHYLITE. *Arsenates*—SCOR DITE, PHARMACOSIDERITE. *Carbonate*—SIDERITE. *Chromate*- CHROMITE. *Columbate*—COLUMBITE. *Tungstate*—WOLFRAMITE.

Economic Importance.

The iron minerals have important and varied uses, which ma briefly be described under the following heads:

I.—In natural state.

II.—For extraction of metal (ores of iron).

III.—For extraction of acid constituents.

IV.—For extraction of included metals.

I.—Uses in Natural State.

In 1898 the production of ocher, umber and sienna and natur oxide paints was 41,950 short tons.* Limonite and hematite a the principal natural oxides ground for paint.

II.—Minerals Used as Ores of Iron.

In the United States the minerals smelted for iron are, in ord of quantity used,† hematite, limonite, magnetite, and siderit Goethite and turgite are commercially included with limonite und the name brown hematite, and more or less ilmenite is smelte with other ores. The residues from the roasting of pyrites a sometimes used as a source of iron, but not in this country.

In 1899 the United States produced 25,341,000‡ long tons iron ore, about three-quarters of which came from the Lake Su perior region of Wisconsin and Minnesota, and about one-sixt came from the Southern States.

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* *Mineral Industry*, 1899.

† John Birkinbine, in *Mineral Resources of United States*, 1892, gives as amoun mined for one year: Hematite, 11,646,619 tons; limonite and goethite, 2,485,1 tons; magnetite, 1,971,965 tons; siderite, 192,981 tons.

‡ *Engineering and Mining Journal*, 1900, p. 3.

The greater portion of the 60,000,000 tons of iron ore produced n the world each year is converted into *pig iron*. That is, the ore s deprived of its oxygen by the action of incandescent carbon and he hot reducing gases resulting from its combustion, and becomes a liquid mass of metallic iron, combined and mixed with a little carbon, silicon, phosphorus, sulphur and other impurities. The furnace used is a vertical shaft, everywhere circular in horizontal section, but usually widening from the top downwards to a certain level, and then again narrowing to the hearth. Hot air is forced nto the furnace through nozzles called tuyères, entering just above he hearth.

The ore and fuel are analyzed and some flux is added, which, when combined with the ash of the fuel and the foreign ingredients of the ore, forms a definite silicate of known fusibility, called the slag. The temperature of the furnace differs at different levels, but is practically the same at all times at any one level.

The ore, charged in at the top, in alternate layers with fuel and flux, passes through zones of different temperatures as it descends, and is reduced, carburized, fused, and flows into the hearth. The slag forms in a definite zone after the complete reduction of the iron, and falls also to the hearth, but, being lighter, floats on the melted iron until drawn off. From time to time the metal is run out into sand moulds, forming the pigs or *pig iron* of which 13,649,453 * long tons were produced in the United States in 1899.

This pig iron, by various processes, is converted into wrought iron, cast-iron and steel.

The mineral franklinite, after treatment for zinc, and certain manganiferous hematites and siderites, are smelted, and yield *spiegeleisen*, an alloy of iron and manganese, used as a source of carbon and manganese in the manufacture of steel.

III.—Minerals Used for Extraction of Acid Constituents.

(*a*) For Sulphur.—Pyrite, and, to a less extent, marcasite and pyrrhotite, are very extensively used in the manufacture of sulphuric acid. In 1898, 363,000 tons were so used in the United States. The sulphides are burned in furnaces with grates, and the gases are converted into sulphuric acid. The residues, in addition to iron, frequently contain copper, nickel or gold, and these are usually extracted later.

* *Engineering and Mining Journal*, 1900, p. 3.

(*b*) FOR ARSENIC.—The mineral arsenopyrite is the chief sourc of arsenic.

(*c*) FOR CHROMIUM.—Practically all the chromium compound derive their chromium from the mineral chromite, very little o which is now mined in the United States. The most importan compounds manufactured are potassium bichromate used in calic printing, oxidizing rubber, bleaching indigo and in manufacturin the chrome paints and matches; potassium chromate used in th manufacture of aniline colors, etc., and ferro-chromium, whic added to steel produces the tough alloy known as chrome-steel

(*d*) FOR TUNGSTEN.—Tungsten and the tungstates are extracte from wolframite and scheelite. The world's product is not mor than 600 to 700 tons, and is chiefly employed in the manufactur of crude tungsten for tungsten steel and sodium tungstate fo rendering fabrics non-inflammable.

IV.—Included Metals.

(*a*) GOLD AND SILVER.—Both pyrite and arsenopyrite frequentl carry gold and a little silver, which may be extracted either directl by stamping and amalgamation or by treatment of the roaste residues with chlorine or potassium cyanide solution.

(*b*) NICKEL.—Pyrrhotite frequently carries nickel, and in 189 about 2,700 tons of nickel were extracted from the pyrrhotite o Sudbury, Ontario.

IRON.

COMPOSITION.—Fe with more or less Ni, Cr, Co, Mn.

GENERAL DESCRIPTION.—Masses and imbedded particles of white to gray metal resembling manufactured iron. Many meteorites are alloys of nickel and iron an usually when polished and etched by dilute acid exhibit lines or bands, due to a crys talline arrangement of alloys of different proportion of Fe to Ni, see Figs. 375, 37

PHYSICAL CHARACTERS.—Opaque. Lustre, metallic. Color, steel-gray to iron black. Streak, metallic gray. H., 4 to 5. Sp. gr., 7.3 to 7.8. Tough and malle able. Fracture, hackly.

BEFORE BLOWPIPE, ETC.—Infusible. Soluble in acids. In borax or salt of phos phorus, reacts only for iron.

FIG. 375.

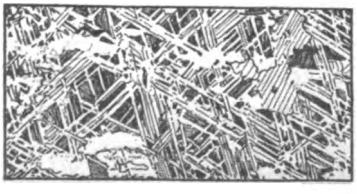


FIG. 376.

Sections of iron meteorites etched with acid.

REMARKS.—Occurs in large masses on Disco Island, Greenland, and sparingly in some basalts, pyrite nodules, etc., and locally reduced by heat from the carbonate. Also found in most meteorites either as chief constituent or as a spongy matrix or in disseminated grains.

PYRRHOTITE.—Magnetic Pyrites, Mundic.

COMPOSITION.—Fe_nS_{n+1}. Fe_6S_7 to $Fe_{11}S_{12}$, with frequently small percentages of cobalt or nickel.

GENERAL DESCRIPTION.—Usually a massive bronze metallic mineral, which is attracted by the magnet and can be scratched with a knife. Sometimes occurs in tabular hexagonal crystals.

Physical Characters. H., 3.5 to 4.5. Sp. gr., 4.5 to 4.6.
LUSTRE, metallic. OPAQUE.
STREAK, grayish-black. TENACITY, brittle.
COLOR, bronze-yellow to bronze-red, but subject to tarnish.
Attracted by the magnet.

BEFORE BLOWPIPE, ETC.—Fuses readily on charcoal to a black magnetic mass, evolves fumes of sulphur dioxide, but does not take fire. In closed tube, yields a little sulphur. In open tube, gives fumes of sulphur dioxide. Soluble in hydrochloric acid, with evolution of hydrogen sulphide and residue of sulphur.

SIMILAR SPECIES.—Pyrrhotite resembles pyrite, bornite and niccolite at times, but differs in being attracted by the magnet and by its bronze color on fresh fracture.

REMARKS.—Pyrrhotite is found in gabbros and schists and occasionally in the older eruptive rocks, also frequently in meteorites. It alters to pyrite, limonite and siderite.

Immense quantities are found at Strafford and Ely, Vermont; Sudbury, Canada, and Lancaster Gap, Pennsylvania. The last two deposits are nickeliferous, and are mined for this metal. Smaller beds are common.

USES.—It is one of the chief ores of nickel, probably from included minerals; and to some extent is an ore of sulphur.

PYRITE.—Iron Pyrites, Fool's Gold.

COMPOSITION.—FeS_2 (Fe 46.7, S 53.3 per cent.), often containing small amounts of Cu, As, Ni, Co, Au.

GENERAL DESCRIPTION.—A brass-colored, metallic mineral, frequently in cubic or other isometric crystals or in crystalline masses, which may be any shape, as botryoidal, globular, stalactitic, etc. Less frequently in non-crystalline masses.

Fig. 377.

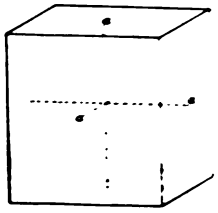


Fig. 378.

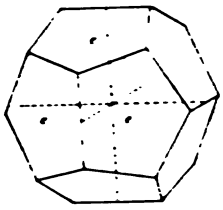


Fig. 379.

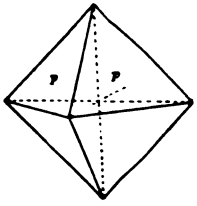


Fig. 380.

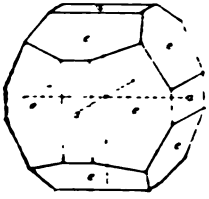


Fig. 381.

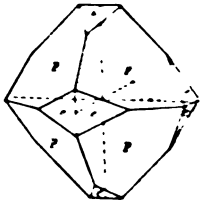


Fig. 382.

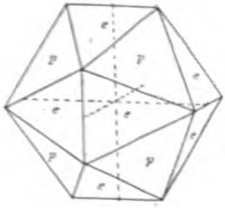


Fig. 383.

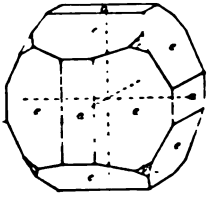


Fig. 384.

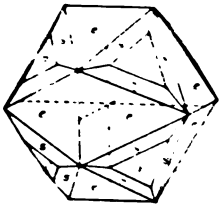
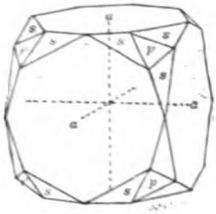


Fig. 385.



Crystallization.—Isometric, class of diploid, p. 20. Most common forms are cube a, Fig. 377, and pyritohedron e, Fig. 378, $2a : \infty a$ or combinations of these, Fig. 380. The octahedron also occurs alone, Fig. 379, or in combination with a and Figs. 381, 382, 383, and the diploid $s = a$ $a : 3a$ is not rare in combinations, Figs. 38 385.

Fig. 386.

Elba.

Twinning parallel to the dodecahedral face described, p. 66, is frequent, Fig. 386.

The faces of the cube and pyritohedron a frequently striated in one direction parallel to i tersections of these two forms.

Physical Characters. H., 6 to 6.5. Sp. gr., 4.9 to 5.2.

Lustre, metallic. Opaque.

Streak, greenish-black. Tenacity, brittle.

Color, pale to full brass-yellow and brown from tarnish.

Cleavage, imperfectly cubic.

BEFORE BLOWPIPE, ETC.—On charcoal, takes fire and burns with a lue flame, giving off fumes of sulphur dioxide, and leaving a magetic residue which, like pyrrhotite, dissolves in hydrochloric acid vith evolution of hydrogen sulphide. In closed tube, gives a ulphur deposit. Insoluble in hydrochloric acid, but soluble in itric acid with separation of sulphur.

SIMILAR SPECIES.—Pyrite is harder than chalcopyrite, pyrrhoite, or gold. It differs from gold, also, in color, streak, and brittleness.

REMARKS.—Pyrite is being formed to-day by the action of the hydrogen sulphide f thermal springs upon soluble iron salts. It has been developed in many rocks by he action of hot water on iron salts in the presence of decomposing organic matter. t may be, also, of igneous origin. Pyrite is found in rocks of all ages, associated vith other metallic sulphides and with oxides of iron. In compact specimens it is not asily altered, but granular masses readily oxidize and are decomposed, forming sulhate of iron and sulphuric acid, thus acting as a vigorous agent in the decomposition f rocks. The final results are usually limonite and sulphates of calcium, sodium, nagnesium, etc. Few minerals are of such general or wide-spread occurrence. The nost celebrated locality is the Rio Tinto region, in Spain, from which immense quanities of a gold- and copper-bearing pyrite are annually procured. The largest deposits vorked in the United States are at Rowe, Mass.; Hermon, N. Y.; and at several ocalities in Virginia. Innumerable large deposits are known.

USES.—Pyrite is burned, for the manufacture of sulphuric acid, n enormous quantities. Pyrite containing copper or gold is sometimes treated for these metals, but, the treatment is frequently preceded by a burning for sulphuric acid. The use of pyrite for the manufacture of copperas has been superseded by a process of galvanizing iron in which copperas is a by-product.

MARCASITE—White Iron Pyrites.

COMPOSITION.—FeS_2, as in pyrite.

GENERAL DESCRIPTION.—Ferric sulphide is dimorphous. Marcasite differs from pyrite in crystalline form, and in little else. It occurs in orthorhombic forms, and in crystalline masses. The compound crystals have given rise to such names as cockscomb pyrites, spear pyrites, etc., from their resemblance to these objects. Often, with radiated structure. Color on fresh fracture is usually whiter than in pyrite.

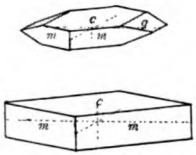
CRYSTALLIZATION.—Orthorhombic, $\dot{a} : \bar{b} : \dot{c} = 0.7662 : 1 : 1.2342$. Crystals usually tabular parallel to base.

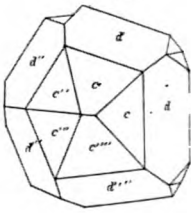
Simple forms show unit prism *m*, basal pinacoid *c* and often one

or more brachy domes as $g = \infty\breve{a} : \bar{b} : \frac{1}{3}\dot{c}$. Compound "five lings" with twin plane m, Fig. 391, are frequent.

Angles are $mm = 105° 5'$, $cg = 157° 39'$.

FIG 387. FIG. 388 FIG. 389. FIG. 391.





Littnitz, Bohemia. Folkstone, Eng. FIG. 390.

Physical Characters. H., 6 to 6.5. Sp. gr., 4.6 to 4.9.

LUSTRE, metallic. OPAQUE.

STREAK, nearly black. TENACITY, brittle.

COLOR, pale brass-yellow, darker after exposure.

CLEAVAGE, imperfect prismatic (angle of 105° 5').

BEFORE BLOWPIPE, ETC.—As for pyrite.

SIMILAR SPECIES.—As for pyrite, from which it is only distinguishable by crystalline form, cleavage, and, to a slight degree, by lighter color.

REMARKS.—Marcasite is more readily decomposed than pyrite, and is, therefore, an even less desirable constituent in building material, etc. It is found at Cummington, Mass.; Warwick, N. Y.; Joplin, Mo.; Haverhill, N. H.; and in many other localities and is usually mistaken for pyrite.

USES, are the same as for pyrite.

ARSENOPYRITE.—Mispickel.

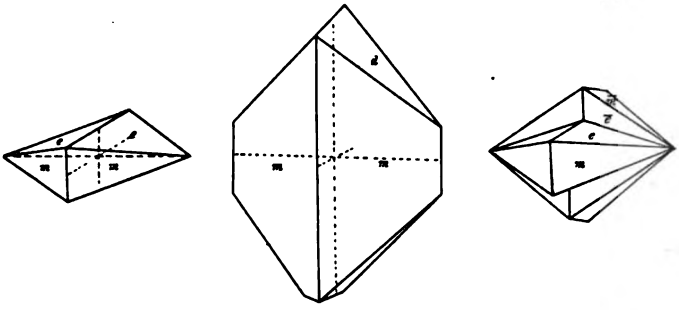
COMPOSITION.—FeAsS. (Fe 34.4, As 46.0, S 19.6 per cent.) sometimes with replacement of iron by cobalt, or arsenic by antimony in part.

GENERAL DESCRIPTION.—Silver white to gray mineral with metallic lustre. Usually compact or in granular masses or disseminated grains. Less frequently in orthorhombic crystals or columnar.

CRYSTALLIZATION. — Orthorhombic $\breve{a} : \bar{b} : \dot{c} = 0.677 : 1 : 1.188$. Common forms, unit prism m combined with a brachy dome either

$= \infty\breve{a} : \bar{b} : c$ or $e = \infty\breve{a} : \bar{b} : \frac{1}{4}c$. Crossed twins, Fig. 394, occur
ıd fivelings, as in Fig. 391 of marcasite.

FIG. 392. FIG. 393. FIG. 394.



Angles $mm = 111° 47'$, $dd = 80° 10'$, $ee = 146° 55'$.

hysical Characters. H. 5.5 to 6. Sp. Gr., 6 to 6.2.

LUSTRE, metallic.
STREAK, grayish-black.
COLOR, silver white to steel gray.
CLEAVAGE, prismatic (111° 47).
OPAQUE.
TENACITY, brittle.

BEFORE BLOWPIPE, ETC.—In closed tube yields a red sublimate, ellow when cold. On charcoal yields abundant white fumes and rsenical odor and coating and fuses to a magnetic globule. After ıort treatment the residue is soluble in hydrochloric acid with volution of hydrogen sulphide and precipitation of the yellow sulhide of arsenic. The residue may react for cobalt. Insoluble in ydrochloric acid. Soluble in nitric acid with separation of sulphur.

SIMILAR SPECIES.—Massive varieties of the metallic cobalt minrals and varieties of leucopyrite resemble arsenopyrite and are nly safely distinguished by blowpipe tests. Smaltite when masve can be distinguished from cobaltiferous arsenopyrite only by s slight reaction with hydrochloric acid after fusion.

REMARKS.—Arsenopyrite is found chiefly in crystalline rocks with other metallic lphides and arsenides. Throughout the Rocky Mountains it is a common mineral ıd frequently auriferous. A large deposit at Deloro, Canada, is mined for both rsenic and gold. The arsenopyrite found in New England usually contains cobalt.

USES.—Arsenopyrite is the source of most of the arsenic of ommerce, and occasionally contains enough gold or cobalt to ay for extraction.

LEUCOPYRITE.—Lollingite.

COMPOSITION.—Fe_3As_4 to $FeAs_2$ sometimes with Co, Ni, Au or S.

GENERAL DESCRIPTION.—Massive silver-white or gray metallic mineral some times occurring in orthorhombic crystals, closely agreeing in angles with crystals o arsenopyrite.

PHYSICAL CHARACTERS.—Opaque. Lustre, metallic. Color, silver-white or gray Streak, grayish-black. H. = 5 to 5.5. Sp. gr., 7 to 7.4. Brittle. Cleavage, basal.

BEFORE BLOWPIPE, ETC.—Like arsenopyrite, except that sulphur reactions are les pronounced or do not appear at all.

MAGNETITE.—Lodestone, Magnetic Iron Ore.

COMPOSITION.—Fe_3O_4 (Fe, 72.4 per cent.) often contains Ti, Mg

GENERAL DESCRIPTION.—A black mineral with black streak and metallic lustre, *strongly* attracted by the magnet and occurring in all conditions from loose sand to compact coarse or fine grained masses.

CRYSTALLIZATION.—Isometric, usually octahedra, Fig. 395, o

FIG. 395.

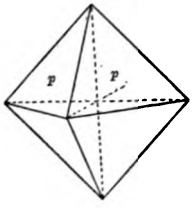


FIG. 396.

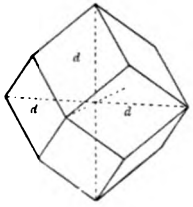
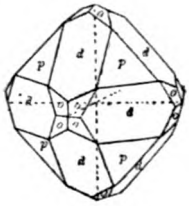


FIG. 397.

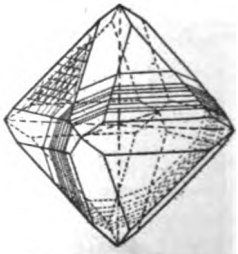


loosely coherent masses of imperfect crystals, sometimes the do decahedron *d*, Fig. 396, or a combination of these, Fig. 399, o

FIG. 398.

Magnetite in Schist, *Geikie.*

FIG. 399.



Port Henry, *Kemp.*

more rarely with the angles modified by the tetragonal trisoctahe dron $o = a : 3a : 3a$, Fig. 397.

winning parallel to an octahedral face occurs, sometimes shown striations upon the octahedral faces, as in Fig. 399.

ysical Characters. H., 5.5 to 6.5. Sp. gr., 4.9 to 5.2.
USTRE, metallic to submetallic. OPAQUE.
OLOR and STREAK, black. TENACITY, brittle.
trongly attracted by magnet and sometimes itself a magnet lestone). Breaks parallel to octahedron.

BEFORE BLOWPIPE, ETC.—Fusible with difficulty in the reduc- flame. Soluble in powder in hydrochloric but not in nitric d.

IMILAR SPECIES.—No other black mineral is strongly attracted the magnet.

EMARKS.—Magnetite occurs chiefly in crystalline metamorphic rocks and in erup- rocks partly derived from silicates containing iron. It is little altered by expo- but organic matter reduces it to ferrous oxide which by oxidation becomes hema- Fe_2O_3.
makes up about 12 per cent. of the iron ore mined in America, being obtained cially from the States of Pennsylvania, New York, New Jersey and Michigan. ller amounts are obtained elsewhere and it is present in many localities. In this ntry, lodestones are obtained mainly from Magnet Cove, Ark. Whole mountains made up of this mineral in Sweden and it is practically the only iron-ore mined in country.

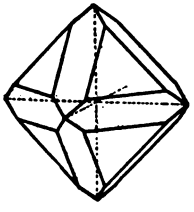
USES—It is an important iron ore highly valued for its purity.

FRANKLINITE.

COMPOSITION.—$(Fe.Mn.Zn)\ (Fe.Mn)_2O_4$.

GENERAL DESCRIPTION.—Black mineral re- mbling magnetite. Occurs in compact sses, rounded grains and octahedral crys- s. Only slightly magnetic and generally h brown streak. The red zincite and yel- w to green willemite are frequent associ- s. The crystals are modified octahedrons ely sharp cut as in magnetite.

FIG. 400.



ysical Characters. H., 6 to 6.5. Sp. Gr., 5 to 5.2.
LUSTRE, metallic or dull. OPAQUE.
STREAK, brown to black. TENACITY, brittle.
COLOR, black.
Slightly magnetic at times. Breaks parallel to octahedron.

BEFORE BLOWPIPE, ETC.—Infusible. On charcoal with so gives white coat of zinc oxide. In beads gives manganese reacti Slowly soluble in hydrochloric acid with evolution of some chlori

SIMILAR SPECIES.—Distinguished from magnetite and chrom by bead tests and associates.

REMARKS.—The only noteworthy locality is that in the vicinity of Franklin F nace, New Jersey. Here, however, the deposit is large and has been extensiv developed.

USES.—The zinc is recovered as zinc white and the residue smelted for spiegeleisen an alloy of iron and manganese used steel manufacture. Franklinite has also been ground for a da paint.

HEMATITE.—Specular Iron, Red Iron Ore.

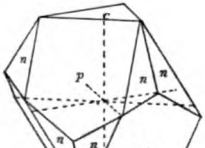
COMPOSITION.—Fe_2O_3, (Fe 70 per cent.), often with SiO_2, Mg etc., as impurities.

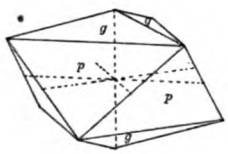
GENERAL DESCRIPTION.—Occurs in masses varying from br liant black metallic to blackish red and brick red with little lust The black is frequently crystallized, usually in thin tabular cry tals set on edge in parallel position, less frequently in larger high modified forms and finally in scale-like to micaceous masses. T red varieties vary from compact columnar, radiated and kidne shaped masses to loose earthy red material. In *all* varieties t streak is *red.*

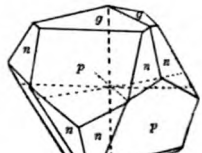
CRYSTALLIZATION.—Hexagonal, scalenohedral class p. 39. A $\dot{c} = 1.36557$.

The most common forms on the Elba crystals are the u rhombohedron p and the scalenohedron $n = \frac{4}{3}a : 4a : a : 2c$. T rhombohedron $g = a : \infty\, a : a : \frac{1}{4}\, c$ also occurs. Thin plate-li

FIG. 401. FIG. 402. FIG. 403,







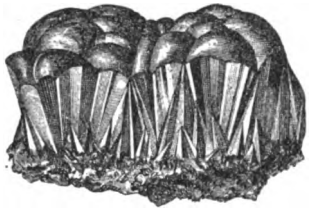
crystals are the rule at other localities. Sometimes grouped rosettes, as in the "Eisenrosen," Fig. 404.

Angles.—$pp = 86°$; $nn = 128° 1'$; $cp = 122° 23'$; $gg = 2° 58'$; $cn = 118° 47'$.

Fig. 404.

Eisenrosen, Fibia Switz.

Fig. 405.



Radiated reniform, *Geikie*.

ysical Characters. H., 5.5 to 6.5. Sp. gr., 4.9 to 5.3.

LUSTRE, metallic to dull.

STREAK, brownish red to cherry red.

COLOR, iron black, blackish red to cherry red. Sometimes slightly magnetic.

OPAQUE.

TENACITY, brittle unless micaceous.

BEFORE BLOWPIPE, ETC.—Infusible. Becomes magnetic in reducing flame. Soluble in hot hydrochloric acid. In borax reacts for iron.

ARIETIES.

Specular Iron.—Brilliant micaceous or in crystals. Black in color.

Red Hematite.—Submetallic to dull, massive, blackish red to brownish red in color.

Red Ochre.—Earthy impure hematite usually with clay. Often pulverulent.

Clay Ironstone.—Hard compact red material mixed with much clay or sand.

Martite.—Octahedral crystals, probably pseudomorphs.

SIMILAR SPECIES.—Resembles at times the other iron-ores and massive cuprite. It is distinguished by its streak and strong magnetism after heating in reducing flame.

REMARKS.—Usually in metamorphic rocks, probably formed from bog iron-ore by pressure and heat. Also found in igneous rocks. Changes by action of atmosphere, water, organic matter, etc., into limonite, siderite and magnetite. About 72 per cent. of the iron-ore mined in the United States is hematite. By far the larger part is obtained from the Marquette and Gogebic ranges of Michigan and from the Mesabi range in Minnesota. Smaller but by no means inconsiderable amounts are mined in New York, Alabama, Missouri and other states.

USES.—In this country it supplies over two-thirds of all the ore mined, and ranks with magnetite in purity. The earthy var are used for a cheap paint, and some massive varieties are gr for paint or polishing material.

ILMENITE.—Menaccanite, Titanic Iron-Ore.

COMPOSITION.—$(Fe.Ti)_2O_3$, sometimes small amounts of M Mn.

GENERAL DESCRIPTION.—An iron-black mineral, usually ma or in thin plates or imbedded grains or as sand. Also, in cry closely like those of hematite in angle.

CRYSTALLIZATION.—Hexagonal. Class of third order rhomb dron p. 46. Axis $\dot{c} = 1.385$. Usually thick plates showing b pinacoid c, unit prism m and unit rhombohedron p, Fig. 40 without the prism, Fig. 406. Angles $pp = 85° 31'$; $cp = 122$

FIG. 406.

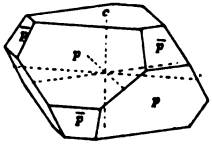
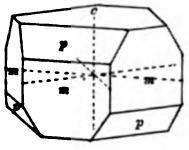


FIG. 407.



Physical Characters.—H., 5 to 6. Sp. gr., 4.5 to 5.

LUSTRE, submetallic.	OPAQUE.
STREAK, black to brownish-red.	TENACITY, brittle
COLOR, iron-black,	Slightly magneti

BEFORE BLOWPIPE, ETC.—Infusible in oxidizing flame; slig fusible in reducing flame. In salt of phosphorus gives a red b which, on treatment in reducing flame becomes violet, slo soluble in hydrochloric acid and the solution boiled with ti violet and on evaporation becomes rose-red.

SIMILAR SPECIES.—Differs from magnetite and hematite in titanium reactions.

REMARKS.—Menaccanite occurs in crystalline rocks, often with magnetite. sometimes altered to limonite and to titanite.

Immense beds occur at Bay St. Paul, Quebec, and other points in Canada. Fo also in the county of Orange, N. Y., in Massachusetts, Connecticut, and elsewher Norwegian locality Kragĕro, is, for its large crystals, perhaps the most celebrated

USES.—It is used as a constituent of the lining of puddling furces. Its freedom from impurities, such as phosphorus, would ake it a very desirable iron-ore if it were not for the relatively rge amount of fuel needed to reduce it.

GOETHITE.

COMPOSITION.—FeO(OH). Fe, 62.9 per cent.

GENERAL DESCRIPTION.—A yellow, red or brown mineral, occurring in small, dis-ct, prismatic crystals (orthorhombic), often flattened like scales, or needle-like, or ouped in parallel position. These shade into feather-like and velvety crusts. Oc-rs also massive like yellow ochre.

PHYSICAL CHARACTERS.—Opaque to translucent. Lustre, adamantine to dull. olor, yellow, reddish, dark-brown and nearly black. Streak, yellow or brownish-yel-w. H., 5 to 5.5. Sp. gr., 4 to 4.4.

BEFORE BLOWPIPE, ETC.—Fuses in thin splinters to a black magnetic slag. In osed tube yields water. Frequently reacts for manganese. Soluble in hydrochloric id.

USES.—Goethite is an ore of iron, but is commercially classed with limonite under e name of brown hematite. Large deposits are reported in Minnesota.

TURGITE.—Hydrohematite.

COMPOSITION.—$Fe_4O_5(OH)_2$, Fe = 66.2 per cent.

GENERAL DESCRIPTION.—Nearly black botryoidal masses and crusts resembling nonite but with a red streak and often with a fibrous and satin-like appearance on acture. Also bright red earthy masses. Usually associated with limonite or hematite.

PHYSICAL CHARACTERS.—Opaque. Lustre, submetallic to dull. Color, dark reddish-ack in compact form to bright red in ocherous variety. Streak, brownish red. ., 5.5–6. Sp. Gr., 4.29–4.68.

BEFORE BLOWPIPE, ETC.—Decrepitates violently, turns black and becomes magnetic. ields water in closed tube with *violent decrepitation*.

SIMILAR SPECIES.—Is distinguished from limonite and hematite by its violent decrepitation when heated.

REMARKS.—Like goethite it is frequently mistaken for and classed ith limonite. It occurs with limonite at Salisbury, Conn., and in arious localities in Prussia and Siberia. It is considered an inter-ediate stage in the formation of hematite from limonite.

USES.—It is an ore of iron but commercially is classed as limonite.

FIG. 408.

Hungary.

LIMONITE.—Bog-Ore, Brown Hematite.

COMPOSITION.— $Fe_2(OH)_6Fe_2O_3$, (Fe, 59.8 per ent.). Frequently quite impure, from sand, clay, anganese, phosphorus, etc.

GENERAL DESCRIPTION.—Never crystallized, but rading from the loose, porous bog-ore and earthy chre of brown to yellow color; to compact varie-ies, often with black varnish-like surface, and fibrous adiated structure. Frequently stalactitic, Fig. 408.

Limonite is recognized principally by its yellowish-brown str and absence of crystallization. It is frequently found pseudomor ous, the original iron-bearing mineral having "changed" to limon

Physical Characters. H., 5 to 5.5. Sp. gr., 3.6 to 4.

LUSTRE, varnish-like, silky, dull. OPAQUE.

STREAK, yellowish-brown, TENACITY, brittle, earth

COLOR, brown, nearly black, yellow like iron rust.

BEFORE BLOWPIPE, ETC.—In closed tube yields water, and comes red. Fuses in thin splinters to a dark magnetic slag. U ally reacts for silica and manganese. Soluble in hydrochlo acid, and may leave a gelatinous residue.

VARIETIES.

Bog-Iron, loosely aggregated ore from marshy ground, of intermixed with and replacing leaves, twigs, etc.

Yellow ochre, *umber*, etc., earthy material, intermixed with cl

Brown clay ironstone, compact, often nodular masses, impu from clay.

SIMILAR SPECIES.—Distinguished from other iron-ores, exc goethite, by its streak, and from the latter by lack of crystalli tion.

REMARKS.—One usual result of the decomposition of any iron-bearing miner limonite. The decomposition by water, carbon dioxide and organic acids, prod soluble iron salts, which are carried to some valley by the streams, and by oxida the relatively insoluble limonite forms as a scum on the water and then sinks to bottom as bog-ore. In time, by pressure, heat, etc., these deposits are compacted.

Limonite constitutes about 15 per cent. of the iron-ore mined in the United St The largest deposits which are regularly mined exist in the States of Virginia, Alaba Pennsylvania, Michigan, Tennessee, and Georgia.

USES.—It is the most abundant ore of iron, but is relativ impure and low in iron. The earthy varieties are used as ch paints, and after burning are darker in color, and are called bu umber, burnt sienna, etc.

COPIAPITE.—Misy.

COMPOSITION.—$Fe_2(FeOH)_2(SO_4)_5 + 18H_2O$, ($Fe_2O_3$ 30.6, S 38.3, H_2O 31.1 per cent.) often with some Al_2O_3 or MgO.

GENERAL DESCRIPTION.—Brownish-yellow to sulphur-yell mineral, occurring granular massive, or in loosely compact crystalline scales, rarely, as tabular monoclinic crystals. It ha disagreeable metallic taste.

hysical Characters. H., 2.5. Sp. gr., 2.1.
LUSTRE, pearly, feeble, TRANSLUCENT.
STREAK, yellowish-white, TASTE, metallic, nauseous.
COLOR, brownish-yellow to sulphur-yellow.

BEFORE BLOWPIPE, ETC.—On charcoal, fuses and becomes mag-
tic. Yields much water in closed tube, and some sulphuric acid.
oluble in water. Decomposed by boiling water. With soda gives
lphur reaction.

REMARKS.—Copiapite results from the oxidation of pyrite, marcasite and pyrrho-
. It occurs with these minerals and with other sulphates.

MELANTERITE.—Copperas.

COMPOSITION.—$FeSO_4 + 7H_2O$. (Fe_2O_3 25.9, SO_3 28.8, H_2O 45.3 per cent.).
GENERAL DESCRIPTION.—A pale green fibrous efflorescence on pyrite or marcasite,
stalactitic massive or pulverulent. It has a sweet astringent taste. Rarely in
noclinic crystals. On exposure it becomes dull yellowish white.
PHYSICAL CHARACTERS.—Translucent. Lustre, vitreous or dull. Color, vitriol
en to white. Streak, white. H., 2. Sp. gr., 1.8 to 1.9. Taste, astringent, sweet-
.
BEFORE BLOWPIPE, ETC.—On charcoal fuses becoming successively brown, red, and
ally black and magnetic. With soda, yields sulphur test. In closed tube yields water
d both sulphuric and sulphurous acids. Soluble easily in water, the solution becom-
black (ink) on addition of nut galls.

VIVIANITE.—Blue Iron Earth.

COMPOSITION.—$Fe_3(PO_4)_2 + 8H_2O$. (FeO 43.0, P_2O_5 28.3, H_2O 28.7 per cent.).
GENERAL DESCRIPTION.—Usually found as a blue to bluish green earthy mineral,
en replacing organic material as in bones, shells, horn, tree roots, etc. Also found
glassy crystals (monoclinic), colorless before exposure, but gradually becoming
e.
PHYSICAL CHARACTERS.—Transparent to opaque. Lustre, vitreous to dull. Color
d streak, colorless before exposure, but usually blue to greenish. H = 1.5 to 2.
gr., = 2.58 to 2.69. Brittle.
BEFORE BLOWPIPE, ETC.—Fuses easily to a black magnetic mass and colors flame
e bluish-green, especially after moistening with concentrated sulphuric acid. In
sed tube yields water. Soluble in hydrochloric acid. The dried powder is brown.

TRIPHYLITE.

COMPOSITION.—$Li(Fe.Mn)PO_4$.
GENERAL DESCRIPTION.—Usually a translucent bluish-gray, massive mineral with
mewhat resinous lustre, and two easy cleavages at 90° to each other. Also in nearly
ck orthorhombic crystals.
PHYSICAL CHARACTERS.—Translucent to opaque. Lustre, resinous. Color, blu-
-gray, green, brown. Streak, white. H., 4.5 to 5. Sp. gr., 3.4 to 3.56. Brittle.
eavages at 90°.

BEFORE BLOWPIPE, ETC.—Fuses easily, coloring the flame carmine red and aft moistening with concentrated sulphuric acid may also show a pale blue tint. Reac in beads for iron and manganese. Soluble in hydrochloric acid.

SCORODITE.

COMPOSITION.—$FeAsO_4 + 2H_2O$. (FeO 34.6 As_2O_5 49.8. H_2O 15.6 per cent.).

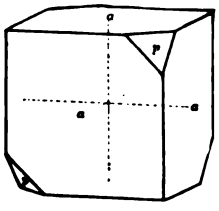
GENERAL DESCRIPTION.—Usually found as small pointed orthorhombic crystals, druses of crystals of either a pale bluish-green or dark brown color. More rare occurs earthy.

PHYSICAL CHARACTERS.—Translucent. Lustre, vitreous. Color, pale green to da brown. Streak, white. H., 3.5 to 4. Sp. gr., 3.1 to 3.3. Brittle.

BEFORE BLOWPIPE, ETC.—On charcoal fuses easily, with a pale blue flame and od like garlic, to a brown or black magnetic mass. Easily soluble in hydrochloric ac but insoluble in nitric acid.

PHARMACOSIDERITE.—Cube Ore.

FIG. 409.



COMPOSITION.—$Fe(FeOH)_3(AsO_4)_3 + 6H_2O$. ($Fe_2O$ 40.0, As_2O_5 43.1 H_2O 16.9 per cent.).

GENERAL DESCRIPTION.—Groups of small translucen cubes or modified tetrahedrons of green or yellowish-brow color. More rarely granular.

PHYSICAL CHARACTERS.—Translucent. Lustre, adaman tine. Color, emerald or olive-green, or yellowish-brown Streak, paler than color. H., 2.5. Sp. gr., 2.9 to 3 Slightly sectile.

BEFORE BLOWPIPE, ETC.—As for scorodite.

SIDERITE.—Spathic Ore.

COMPOSITION.—$FeCO_3$ (FeO 62.1, CO_2 37.9 per cent.) usuall with some Ca, Mg or Mn.

FIG. 410.

GENERAL DESCRIPTION.—Occurs granular massive of a gray or brown color and also in masses with rhombohedral cleavage and rhombohedral crystals. At times it is quite black from included carbonaceous matter.

CRYSTALLIZATION.—Hexagonal. Scalenohedral class p. 39. Axis $\dot{c} = 0.8184$. Usually rhombohedrons of 107°, often with curved (composite faces like those of dolomite. Optically,—with strong double re fraction.

Physical Characters. H., 3.5 to 4. Sp. gr., 3.83 to 3.88.
LUSTRE, vitreous to pearly. OPAQUE to translucent.
STREAK, white or pale yellow. TENACITY, brittle.
COLOR, gray, yellow, brown or black.
CLEAVAGE, rhombohedral $R \wedge R = 107°$.

BEFORE BLOWPIPE, ETC.—Decrepitates, become black and magetic and fuses with difficulty. Soluble in warm acids with efferescence. Slowly soluble in cold acids. May react for mananese.

SIMILAR SPECIES.—It is heavier than dolomite and becomes magetic on heating. Some stony varieties resemble varieties of sphalrite.

REMARKS.—Siderite occurs as beds in gneiss, mica and clay-slate, etc., and as ony impure material in the coal formation. Frequently with metallic ores. It is robably chiefly formed by the action of decaying vegetation on limonite. An impure derite forms the chief ore in Cornwall and other English mines. It is found at Catsill, N. Y., and in the coal regions of Pennsylvania, Ohio, Virginia, and Tennessee, varying quantities, but forms only a little over one per cent. of American iron ore.

USES.—It is used as an ore of iron and when high in manganese t is used for the manufacture of spiegeleisen.

CHROMITE.—Chromic Iron.

COMPOSITION.—$FeCr_2O_4$, (FeO 32, Cr_2O_3 68 per cent.), sometimes with Al_2O_3 or MgO as replacing elements.

GENERAL DESCRIPTION.—Usually a massive black mineral resembling magnetite. Occurs either granular or compact or as disseminated grains. Rarely in small octahedral crystals. Frequently with more or less serpentine, mechanically intermixed, giving rise o green and yellow spots and streaks.

Physical Characters. H., 5.5. Sp. gr., 4.3 to 4.6.
LUSTRE, sub-metallic to metallic. OPAQUE.
STREAK, dark-brown. TENACITY, brittle.
COLOR, black. May be slightly magnetic.

BEFORE BLOWPIPE, ETC.—Infusible, sometimes slightly fused by reducing flame, and *then* becomes magnetic. In salt of phosphorus, in oxidizing flame, gives yellow color hot, but on cooling becomes a fine emerald-green. With soda and nitre on platinum fuses to a mass, which is chrome-yellow when cold. Insoluble in acids.

SIMILAR SPECIES.—Chromite is distinguished from other black minerals by the salt of phosphorus reactions, and to a considerable extent by the serpentine with which it occurs.

REMARKS.—Chromite occurs in veins and masses in serpentine and has been found in large isolated pockets in Southern Pennsylvania and around Baltimore, Md., but the richest ore has been exhausted, and most of the ore now used is brought from Turkey and from New Caledonia. Extensive deposits are also found in Del Norte, San Luis Obispo, Shasta and Placer Counties, California, but of somewhat lower grade.

USES.—Chromite is the source of the various chromium compounds, such as potassium bichromate, the chrome colors, etc. It is also used in the manufacture of a hard chrome steel.

COLUMBITE.—Tantalite.

COMPOSITION.—$Fe(CbO_3)_2$, (FeO 17.3, Cb_2O_5 82.7), but grading into tantalite, $Fe(TaO_3)_2$ without change of crystalline form. Mn is often present.

GENERAL DESCRIPTION.—Black, often iridescent prismatic crystals, in veins of granite. More rarely massive.

PHYSICAL CHARACTERS.—Opaque. Lustre, bright sub-metallic. Color, black. Streak, dark-red to black. H., 6. Sp. Gr., 5.4 to 6.5. Brittle. Cleavage in two directions at right angles.

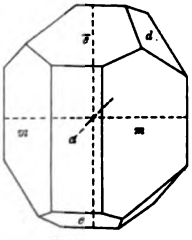
BEFORE BLOWPIPE, ETC.—Infusible. Fused with potassium hydroxide and boiled with tin gives deep-blue solution. Insoluble in acids.

WOLFRAMITE.

COMPOSITION.—(Fe.Mn) WO_4. (About 76.5 per cent. WO_3.)

GENERAL DESCRIPTION.—Heavy dark-gray to black sub-metallic crystals, orthorhombic in appearance, and also in granular or columnar masses.

Fig. 411.



Zinnwald.

CRYSTALLIZATION.—Monoclinic. Axes $\dot{a} : \bar{b} : \dot{c} = 0.830 : 1 : 0.868$, $\beta = 89° 22'$.

Usual combination shown in Fig. 411 of unit prism m, ortho pinacoid a, unit clinodome d and + and − ortho domes $e = \breve{a} : \infty\ \bar{b} : \frac{1}{2} c$. Angles $mm = 100° 37'$; $dd = 98° 6'$; $ae = 118° 6'$; $ae = 117° 6'$.

Physical Characters. H., 5 to 5.5. Sp. gr., 7.1 to 7.55.

LUSTRE, sub-metallic. OPAQUE.

STREAK, dark-brown to black. TENACITY, brittle.

COLOR, dark-gray to black. Slightly magnetic.

BEFORE BLOWPIPE, ETC.—Fuses readily to a crystalline globule, hich is magnetic. In salt of phosphorus yields a reddish-yellow ass, which in reducing flame becomes green, and if this bead is ılverized and dissolved with tin, in dilute hydrochloric acid, a ue solution results.

Partially soluble in hydrochloric acid, the solution becoming lue on addition of tin.

SIMILAR SPECIES.—Distinguished by its fusibility and specific ravity from similar iron and manganese minerals.

REMARKS.—Wolframite occurs in tin veins and deposits and with other metallic inerals. It occurs altered to Scheelite and also pseudomorphous after scheelite. It common in the Cornwall and Zinnwald tin mines. It is also found at Flowe Mountin, N. C., Monroe and Trumbull, Ct., Black Hills, Dakota, Mine la Motte, Mo., and sewhere.

USES.—It is used to make an alloy of tungsten with steel, especially valued for permanent magnets, and as a source of tungsten alts, especially tungstic acid and sodium tungstate, which are used n dyeing, and as material to render cotton less imflammable.

CHAPTER XXI.

THE MANGANESE MINERALS.

The minerals described are* *Sulphide.*—ALABANDITE. *Oxides.*—BRAUNITE, HAUSMANNITE, PYROLUSITE, MANGANITE, PSILOMELANE, WAD. *Phosphates.*—TRIPLITE. *Carbonate.*—RHODOCHROSITE.

The principal economic use of manganese minerals is in the production of the alloys with iron, *spiegeleisen* and *ferromanganese* used in the manufacture of steel. About nine-tenths of all the manganese ore mined is used for this purpose. The method of smelting is very like that used in the manufacture of pig-iron.

Minor uses are in the manufacture of chlorine, oxygen, disinfectants, driers for varnishes; as a decolorizer of glass and to color glass, pottery and bricks; in dyeing calico, making paints, etc.

In the West, especially Colorado and Arizona, manganese ores often carry silver, and several thousand tons are smelted each year with other silver-bearing minerals, the manganese acting as a flux.

The manganese minerals important as ores are the oxides pyrolusite, psilomelane (including wad), braunite and manganite. In 1898 the United States produced 217,782 long tons of manganese ore.†

ALABANDITE.—Manganblende.

COMPOSITION.—MnS, (Mn 63.1, S 36.9 per cent.).

GENERAL DESCRIPTION.—A dark iron-black metallic mineral with an olive green powder or streak. Usually massive, with easy cubic cleavage and occasionally in cubic or other isometric crystals. Also massive granular.

PHYSICAL CHARACTERS.—Opaque. Lustre, metallic. Color, deep black with brown tarnish. Streak, olive green. H., 3.5 to 4. Sp. gr., 3.95 to 4.04. Brittle.

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* The common silicate, rhodonite, which has no economic importance, is described under the silicates.

† *Mineral Industry*, 1899, p. 499.

BEFORE BLOWPIPE, ETC.—Turns brown, evolves sulphur dioxide and fuses. Gives sulphur reactions with soda. Soluble in dilute hydrochloric acid with rapid evolution of hydrogen sulphide.

SIMILAR SPECIES.—It is distinguished from all similar species by its streak.

REMARKS.—The other manganese minerals are derived in part from the alteration of this species. It occurs with other metallic sulphides.

BRAUNITE.

COMPOSITION.—Mn_2O_3, but usually containing $MnSiO_3$.

GENERAL DESCRIPTION.—Brownish black granular masses and occasional minute tetragonal pyramids almost isometric, $c = 0.985$.

Physical Characters. H., 6 to 6.5. Sp. gr., 4.75 to 4.82.

LUSTRE, submetallic. OPAQUE.

STREAK, brownish black. TENACITY, brittle.

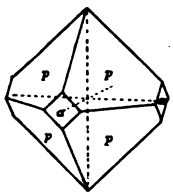
COLOR, brownish black to steel gray.

BEFORE BLOWPIPE, ETC.—Infusible. With borax an amethystine bead. Soluble in hydrochloric acid, evolving chlorine and generally leaving gelatinous silica.

SIMILAR SPECIES.—Resembles hausmannite, but has a darker streak and is harder.

USES.—It occurs in large quantities in India and smaller amounts elsewhere, and is an ore of manganese.

FIG. 412.



Braunite $pp = 102° 15'$.

FIG. 413.

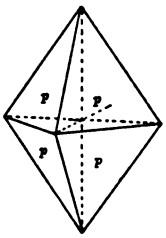
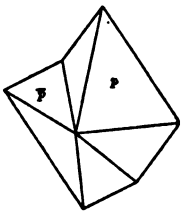


FIG. 414.



Hausmannite, $pp = 105° 26'$.

HAUSMANNITE.

COMPOSITION.—Mn_3O_4. (Mn_2O_3 69.0, MnO 31.0 per cent.).

GENERAL DESCRIPTION.—Black granular strongly coherent masses occasionally in simple and twinned tetragonal pyramids which are more acute than those of braunite, $c = 1.174$.

PHYSICAL CHARACTERS.—Opaque. Lustre, submetallic. Color, brownish black. Streak, chestnut brown. H., 5 to 5.5. Sp. gr., 4.72 to 4.85. Strongly coherent.

BEFORE BLOWPIPE, ETC.—Infusible. Colors borax bead amethystine. Soluble in hydrochloric acid with evolution of chlorine.

SIMILAR SPECIES.—Differs from braunite in hardness, streak and absence of silica.

PYROLUSITE.—Black Oxide of Manganese.

COMPOSITION.—MnO_2, (Mn 63.2 per cent.).

FIG. 415.

Florence, Italy.

GENERAL DESCRIPTION.—soft black mineral of metal lustre. Frequently compos of fibres or columns often r diated, but also found fi grained, massive, stalactit and as velvety crusts. It also the common dendrit Fig. 415. Usually soils t fingers. Frequently in alte nate layers with psilomelan

Physical Characters. H., 1 to 2.5. Sp. gr., 4.7 to 4.86.
LUSTRE, metallic or dull. OPAQUE.
STREAK, black. TENACITY, rather brittle.
COLOR, black to steel gray.

BEFORE BLOWPIPE, ETC.—Infusible, becomes brown. Usual yields oxygen and a little water in closed tube. Colors bor bead amethystine. Soluble in hydrochloric acid with evolution chlorine.

SIMILAR SPECIES.—Distinguished by its softness and black strea from other manganese minerals.

REMARKS.—Pyrolusite results from the dehydration of manganite and the alte tion of alabandite and rhodochrosite. It is usually with psilomelane, hematite, limo ite or manganite.

By far the larger part of all that is mined in this country is obtained from Crimet Va., Cartersville, Ga., and Batesville, Ark. Other deposits exist in California, Ve mont and North Carolina. Large amounts are annually imported from Cuba. T purest material for use in glass making is obtained near Sussex, N. B., and from t Tenny Cape district, Nova Scotia.

USES.—Pyrolusite is used in the manufacture of chlorine an oxygen, and in the preparation of spiegeleisen. Also in colorin and decolorizing glass and as an oxidizing agent in varnishes linseed oil, etc.

MANGANITE.

COMPOSITION.—$MnO(OH)$, (Mn 62.4, O 27.3, H_2O 10.3 per cent.)
GENERAL DESCRIPTION.—Occurs in long and short prismati

rthorhombic) crystals often grouped in bundles with fluted or unded cross-section and undulating terminal surface, rarely mass-, granular or stalactitic.

ysical Characters, H., 4. Sp. gr., 4.2 to 4.4.

LUSTRE, submetallic. OPAQUE.
STREAK, reddish brown to black. TENACITY, brittle.
COLOR, steel gray to iron black.

BEFORE BLOWPIPE, ETC.—Like pyrolusite, but yields *decided* test r water and very little oxygen.

REMARKS.—Frequently formed by deposition from water. By alteration it forms ier manganese minerals such as pyrolusite.

PSILOMELANE.—Black Hematite.

COMPOSITION.—Perhaps MnO_2 + (H_2O, K_2O or BaO) or H_4MnO_5, ith replacement by Ba or K.

GENERAL DESCRIPTION.—A smooth black massive mineral com- only botryoidal, stalactitic or in layers with pyrolusite. Never ystallized.

hysical Characters. H., 5 to 6. Sp. gr., 3.7 to 4.7.

LUSTRE, submetallic or dull. OPAQUE.
STREAK, brownish black. TENACITY, brittle.
COLOR, iron black to dark gray.

BEFORE BLOWPIPE, ETC.—Infusible.* In closed tube yields xygen and usually water. Soluble in hydrochloric acid, with volution of chlorine. A drop of sulphuric acid added to the solu- on will usually produce a white precipitate of barium sulphate.

SIMILAR SPECIES.—Distinguished from pyrolusite by its hard- ess, and from limonite by its streak.

REMARKS.—Its localities are the same as for pyrolusite, and the two minerals are ually mined together.

USES.—As for pyrolusite; the products, however, are less pure.

WAD.—Bog Manganese.

COMPOSITION.—Mixture of manganese oxides, with often oxides of metals other than anganese such as cobalt, copper and lead.

GENERAL DESCRIPTION.—Earthy to compact indefinite mixtures of different metal- oxides, in which those of manganese predominate. Dark brown or black in color; ten soft and loose, but sometimes hard and compact.

* May become magnetic from impurities.

PHYSICAL CHARACTERS.—Opaque. Lustre dull. Color brown to black. Str brown. H., ½ to 6. Sp. gr., 3 to 4.26. Often soils the fingers.

BEFORE BLOWPIPE, ETC.—As for psilomelane, but often with strong cobalt copper reactions.

USES.—Wad is used as a paint and in the manufacture of chlorine.

TRIPLITE.

COMPOSITION.—$(RF)RPO_4$. R chiefly manganese and iron.

GENERAL DESCRIPTION.—A resinous, brown to nearly black mineral, usu massive and often showing cleavage in two directions at 90° to each other. Sometii occurs as a stain on other minerals.

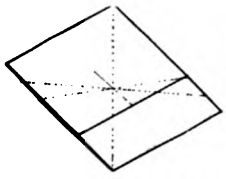
PHYSICAL CHARACTERS.—Opaque or nearly so. Lustre resinous. Color brow nearly black. Streak gray to brown. H., 4 to 5. Sp. gr., 3.44 to 3.8.

BEFORE BLOWPIPE, ETC.—Fuses very easily to a black magnetic mass. Yield bluish-green flame, which sulphuric acid makes plainer. Colors borax bead ameth tine. When heated with sulphuric acid, evolves fluorine. Soluble in hydrochl acid.

RHODOCHROSITE.

COMPOSITION.—$MnCO_3$, (MnO 61.7, CO_2 38.3 per cent.) w partial replacement by Ca, Mg or Fe.

FIG. 416.



GENERAL DESCRIPTION.—Occurs in rho bohedral crystals, but more frequently mass cleavable, or granular or compact. Less f quently botryoidal or incrusting.

CRYSTALLIZATION. — Hexagonal. Scalen hedral class, p. 39. Axis $\dot{c} = .8184$. Ang as in siderite. Usual form a rhombohedron of 107°. Optically

Physical Characters. H., 3.5 to 4.5. Sp. gr., 3.3 to 3.6.

LUSTRE, vitreous to pearly. TRANSPARENT to opaque.

STREAK, white. TENACITY, brittle.

COLOR, light pink, rose red, brownish red and brown.

CLEAVAGE, parallel to rhombohedron (angle 107°).

BEFORE BLOWPIPE, ETC.—Infusible, but decrepitates violent and becomes dark colored.* In borax yields amethystine bea Soluble in warm hydrochloric acid, with effervescence, slowly s uble in the cold acid.

SIMILAR SPECIES.—Distinguished from rhodonite by form, clea age, effervescence and infusibility.

REMARKS.—Principally found in ore-veins, especially with ores of manganese a silver. On exposure, sometimes loses color or becomes spotted by oxide. Found Mine Hill, N. J.; Butte, Montana; Austin, Nev. and elsewhere. It is not min however, in this country. The only producing localities are Merionethshire, Wal and Chevron, Belgium.

* May become magnetic from impurities.

CHAPTER XXII.

NICKEL AND COBALT MINERALS.

THE COBALT MINERALS.

The cobalt minerals described are: *Sulphides and Arsenides*, LINNÆITE, COBALTITE, SMALTITE; *Arsenates*, ERYTHRITE.

The metal cobalt has, as yet, no important use; the oxide is used to impart a blue color to glass and pottery. The chief commercial compound is SMALT, a cobalt glass, the cobalt replacing the calcium of ordinary glass. This is ground and used as a fine blue pigment, which is unaltered by exposure.

Cobalt blue and Rinmann's green are compounds of cobalt with alumina and zinc oxide respectively.

The extraction of cobalt from a nickeliferous matte is an elaborate chemical operation involving solution in hydrochloric acid, precipitation of manganese and iron as basic carbonates, and of other metals as sulphides, leaving a solution of chloride of nickel and cobalt. From these the cobalt is precipitated with great care, by means of calcium hypochlorite, as cobaltic hydroxide, after which the nickel is precipitated as hydroxide by lime-water. By using selected ores, mattes especially rich in cobalt may be obtained and for ordinary purposes the small nickel contents are neglected.

LINNÆITE.—Cobalt Pyrites.

COMPOSITION.—$(Co.Ni)_3S_4$, often with some Fe or Cu replacing.

GENERAL DESCRIPTION.—A steel-gray metallic mineral, usually granular or compact masses intermixed frequently with chalcopyrite; also in small isometric crystals, usually the octahedron *p*, Fig. 417, or this with the cube *a*, Fig 418.

FIG. 417.

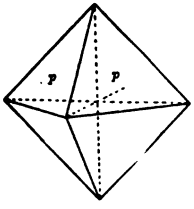
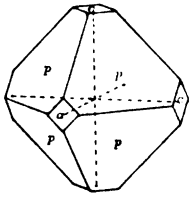


FIG. 418.



*Cobalt is sometimes found in arsenopyrite. Asbolite is a black earthy oxide of cobalt and manganese.

Physical Characters. H., 5.5. Sp. gr., 4.8 to 5.

LUSTRE, metallic. OPAQUE.

STREAK, nearly black. TENACITY, brittl

COLOR, steel-gray, with reddish-tarnish.

CLEAVAGE, cubic imperfect.

BEFORE BLOWPIPE, ETC.—On charcoal fuses to a magnetic g ule, and gives off fumes of sulphur dioxide. In borax bead giv deep blue color, and with frequent replacement of borax the bead of nickel may be obtained. Soluble in nitric acid to a solution and with separation of sulphur.

REMARKS.—Occurs with other cobalt and nickel minerals and with chalcop pyrrhotite, bornite, at Mine La Motte, Mo., Lovelock's Station, Nev., and in a other American localities.

USES.—Does not occur in large amounts, but is used as a sou of both cobalt and nickel.

COBALTITE.—Cobalt Glance.

COMPOSITION.—CoAsS, (Co 35.5, As 45.2, S 19.3 per cent.

GENERAL DESCRIPTION.—A silver white to gray metallic m eral resembling linnæite in massive state but in crystals differing that the forms are the pyritohedron *e*, and cube *a*, and these co bined, Fig. 421.

FIG. 419.

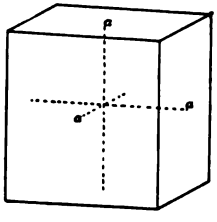


FIG. 420.

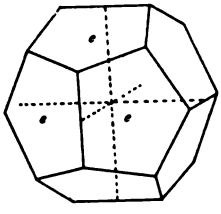
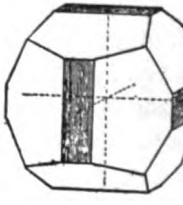


FIG. 421.



Physical Characters. H., 5.5. Sp. gr. 6 to 6.1.

LUSTRE, metallic. OPAQUE.

STREAK, black. TENACITY, brittle.

COLOR, silver white to gray. CLEAVAGE, cubic.

BEFORE BLOWPIPE, ETC.—On charcoal fuses to a magnetic gl ule and evolves white fumes with garlic odor. Unaltered in clo tube. Soluble in warm nitric acid to rose-red solution, with r due of sulphur and arsenous oxide.

USES.—It is used in the manufacture of smalt and in porcelain inting.

SMALTITE.

COMPOSITION.—(Co.Ni) As_2, varying widely in proportion of balt and nickel, and usually containing some iron also.

GENERAL DESCRIPTION.—A tin-white to steel-gray metallic min-al resembling linnæite and cobaltite. Usually occurs granular assive, but also in isometric crystals, especially modified cubes ith curved faces.

hysical Characters. H., 5.5 to 6. Sp. gr., 6.4 to 6.6.

LUSTRE, metallic. OPAQUE.
STREAK, black. TENACITY, brittle.
COLOR, tin-white to steel-gray. CLEAVAGE, octahedral.

BEFORE BLOWPIPE, ETC.—On charcoal fuses, yields white fumes ith garlic odor and leaves a magnetic residue, which, when oxi-zed in contact with frequently replaced borax, yields successively ags colored by iron, cobalt, nickel and possibly by copper. In osed tube yields arsenical mirror. Soluble in nitric acid to a red green solution according to proportion of cobalt and nickel. artially soluble in hydrochloric acid, especially so after fusion, ut yields no voluminous precipitate of yellow arsenic sulphide, does arsenopyrite when similarly treated.

SIMILAR SPECIES.—Differs from linnæite and cobaltite in cleav-ge, specific gravity and blowpipe reactions. Differs from most rsenopyrite and tetrahedrite in the cobalt blue slags which it ields. It can best be distinguished from cobaltiferous arseno-yrite by the reaction in acids after fusion.

REMARKS.—By oxidation produces arsenates of cobalt (erythrite) and nickel (an-bergite). Occurs in veins with other metallic minerals, especially ores of copper, ver, nickel and cobalt. Especially abundant in the nickel mines of Saxony. Found Chatham, Ct., Franklin Furnace, N. J., and in California.

USES.—It is the chief ore of cobalt.

ERYTHRITE.

COMPOSITION.—$Co_3(AsO_4)_2.8H_2O$, (CoO 37.5, As_2O_5 38.4, H_2O 24.1 per cent.).

GENERAL DESCRIPTION.—Groups of minute peach red or crimson crystals forming drusy or velvety surface. Also in small globular forms or radiated or as an earthy crustation of pink color.

PHYSICAL CHARACTERS.—Translucent. Lustre, adamantine or pearly. Col crimson, peach red, pink and pearl gray. Streak, paler than color. H., 1.5 to 2 Sp. gr., 2.91 to 2.95. Flexible in laminæ.

BEFORE BLOWPIPE, ETC.—On charcoal fuses easily, evolves white fumes with gar odor, and leaves a magnetic residue, which imparts the characteristic blue to bor bead. Soluble in hydrochloric acid to a light red solution.

THE NICKEL MINERALS.

The nickel minerals described are: *Sulphides*, MILLERIT PENTLANDITE, GERSDORFFITE; *Arsenides*, NICCOLITE, CHLOA THITE; *Arsenate*, ANNABERGITE; *Carbonate*, ZARATITE; *Silica* GARNIERITE.

Metallic nickel is extensively used in different alloys, and, i deed, was first obtained as a residual alloy with copper, iron a arsenic, in the manufacture of smalt. This alloy was called Ge man silver or nickel silver and largely used in plated silverwa Later, a large use for nickel was found in coins, the United Stat Mint alone using nearly one million pounds between 1857 a 1884. In this alloy copper is in large proportion, the prese five cent piece being 25 per cent. nickel, 75 per cent. copper, a in other coins the percentage of copper being still greater. T most extensive application of nickel at present is in the manufa ture of nickel steel for armor plates and other purposes. T uses of nickel steel are continually increasing as the metal h some excellent properties possessed by no other alloy. To limited extent nickel is used in a nickel-copper alloy for casi rifle bullets.

A sulphate of nickel and ammonium is also manufactured large amounts for use in nickel plating.

The nickel of commerce is nearly all obtained either from t garnierite of New Caledonia or from the deposit of nickel-bearir sulphides at Sudbury, Ontario. The garnierite is smelted in low blast furnace, with coke and gypsum, and the matte of nick iron and sulphur thus produced is alternately roasted and fus with sand, in a reverberatory furnace, until nearly all the iron h been removed. The nickel sulphide, by oxidation, is converte into oxide.

Nickel oxide is obtained from the pyrrhotite and chalcopyri of Sudbury, Canada. The ore is first roasted, which remov much of the sulphur, and is then smelted, together with nick bearing slags of previous operations. A nickel matte carryin

nuch copper and some iron is produced through which air is lown in a silica lined Bessemer converter and most of the iron is arried into the slag. A matte, rich in nickel and copper, results. This may be directly roasted and reduced by carbon to produce ickel-copper alloys for the manufacture of German silver. In rder to separate the nickel the concentrated matte is fused with odium sulphate and coke, after which the melted sulphides are llowed to settle. Under these conditions the copper and iron ulphides form a very fluid mass with the soda, and, with some ickel, rise to the top while the lower portions of the mass are ighly nickeliferous. The two layers are separated and each is treated in much the same manner. The nickel sulphide result- ng is partially roasted and is fused with sand, by means of which nost of the iron is removed as a silicate in the slag. The nickel ulphide remaining is by oxidation converted into the oxide. The xide is sold directly to steel makers or may be reduced to metal y mixing with charcoal and heating, white hot, in a graphite rucible.

The world's annual output of nickel is about 6000 short tons.

Nickel is now successfully refined by electrolysis, but the de- ails of the process are jealously guarded. It is doubtful, however, nickel can be separated from cobalt in this manner although nost other impurities are removed.

A method both for the extraction of nickel from its ore and for s separation from cobalt promises to supersede those now in use. The process is based on the discovery that when carbon monoxide passed over heated nickel, volatile nickle carbonyl, $Ni(CO)_4$, formed. This is the only volatile nickel compound known, nd as cobalt does not react in this way, the separation of nickel rom cobalt is easily accomplished. The reconversion of the ickel carbonyl into nickel and carbon monoxide is a simple peration.

MILLERITE.—Capillary Pyrites.

COMPOSITION.—NiS, (Ni 64.4 per cent.).

GENERAL DESCRIPTION.—A brass-colored mineral with metallic ustre, especially characterized by its occurrence in hair-like or eedle crystals, often interwoven or in crusts made up of radiating eedles visible on fracture. Hexagonal.

Physical Characters. H., 3 to 3.5. Sp. gr., 5 3 to 5.65.
LUSTRE, metallic. OPAQUE.
STREAK, greenish-black. TENACITY, crystals elastic.
COLOR, brass or bronze yellow.

BEFORE BLOWPIPE, ETC.—On charcoal spirts and fuses to brittle magnetic globule, which will color borax red. Soluble aqua regia to a green solution, from which potassium hydroxi precipitates a green nickelous hydroxide which is again soluble ammonia to a blue solution.

REMARKS.—Millerite has probably been formed in the same way as pyrite. It probable that the nickel in pyrrhotite is there as millerite. Other associates a siderite, hematite and dolomite. In the United States it has been obtained chie from the Lancaster Gap mine, in Pennsylvania, and at Antwerp, N. Y.

USES.—It is a valued ore of nickel.

PENTLANDITE.

COMPOSITION.—(Fe.Ni)S.

GENERAL DESCRIPTION.—Light bronze-yellow, granular masses of metallic lust usually with chalcopyrite or pyrrhotite.

PHYSICAL CHARACTERS.—Opaque. Lustre, metallic. Color, bronze yello Streak, black. H., 3.5–4. Cleavage, octahedral. Sp. gr., 4.6–5. Brittle.

BEFORE BLOWPIPE, ETC.—Fuses readily to a magnetic globule which reacts for ir and nickel.

REMARKS.—Occurs at Sudbury, Ontario, where it is mined for nickel.

GERSDORFFITE.

COMPOSITION.—NiAsS (Ni 35.4, As 45.3, S 19.3 per cent.) Ni often replaced Fe or Co.

GENERAL DESCRIPTION.—Usually massive, fine grained light steel gray. Occasio ally small isometric crystals like those of pyrite.

PHYSICAL CHARACTERS.—Opaque. Lustre, metallic. Color, light-steel gray. Streal black. Brittle. H., 5.5, Sp. gr., 5.8–6.2.

BEFORE BLOWPIPE, ETC.—Fuses easily with decrepitation to a metallic globule givi off white fumes of arsenic trioxide. Residue is magnetic, and gives sulphur reactio Borax bead may yield nickel reaction, but this is often masked by cobalt or iron.

REMARKS.—Various uncertain minerals or mixtures have been referred to gersdorffit It occurs incrusting decomposed galenite and sphalerite at Phœnixville, Pa., and Sweden, Harz, Styria, etc.

NICCOLITE.—Copper Nickel.

COMPOSITION.—NiAs, (Ni 43.9 per cent.). As is replaced t some extent by Sb or S, and Ni by Fe or Co.

GENERAL DESCRIPTION.—A massive mineral of metallic lustre characteristic pale copper red color and smooth impalpable struct ure. Sometimes the copper-red kernel has a white metallic crust Occasionally occurs in small indistinct hexagonal crystals.

hysical Characters. H., 5 to 5.5. Sp. gr., 7.3 to 7.67.
LUSTRE, metallic. OPAQUE.
STREAK, brownish-black. TENACITY, brittle.
COLOR, pale copper red with dark tarnish.

BEFORE BLOWPIPE, ETC.—On charcoal fuses easily, giving off hite fumes with garlic odor and leaving a magnetic residue, which ill color borax bead red and sometimes blue, in which case ne borax must be renewed until the cobalt is all removed. In pen tube yields a white sublimate and a yellowish-green pul-erulent residue. Soluble in concentrated nitric acid to a green olution, which may be tested as under millerite.

SIMILAR SPECIES.—Differs from copper in hardness, black treak and brittleness.

REMARKS.—Its most abundant American localities are at Lovelock's, Nevada, and ilt Cove, Newfoundland. Also obtained at Chatham, Conn., and Thunder Bay, ake Superior.

USES.—It is an important ore of nickel.

CHLOANTHITE.

COMPOSITION.—$NiAs_2$. Ni 28.1 per cent., Ni often replaced by Fe and Co.
GENERAL DESCRIPTION.—Tin white to steel gray metallic mineral which resembles naltite, and by replacement of nickel by cobalt gradually grades into that mineral.
PHYSICAL CHARACTERS.—Like smaltite.
BEFORE BLOWPIPE, ETC.—Like smaltite except that a nickel reaction is imparted to orax by the pure mineral.

ANNABERGITE.—Nickel Bloom.

COMPOSITION.—$Ni_3(AsO_4)_2.8H_2O$, (NiO 37.4 As_2O_5 38.5, H_2O 24.1 per cent.).
GENERAL DESCRIPTION.—Pale apple-green crusts, and occasionally very small air-like crystals. Usually occurs on niccolite or smaltite.
PHYSICAL CHARACTERS.—Dull. Color, apple-green. Streak, greenish-white. H., 1.
BEFORE BLOWPIPE, ETC.—On charcoal, fuses easily to a magnetic button, and be-omes dull and yellow during fusion, evolving garlic odor. In closed tube, yields ater and darkens. With borax, gives red bead. Soluble in nitric acid.
REMARKS.—Results from the oxidation of niccolite or smaltite in moist air.

ZARATITE.—Emerald Nickel.

COMPOSITION.—$NiCO_3\ 2Ni(OH)_2.4H_2O$, (NiO 59.6 CO_2 11.7 H_2O, 28.7 per cent.).
GENERAL DESCRIPTION.—Occurs only as a thin varnish-like coating upon nickel-earing chromite or magnetite.
PHYSICAL CHARACTERS.—Translucent. Lustre, vitreous. Color, emerald-green. treak, pale-green. H., 3 to 3.25. Sp. gr., 2.57 to 2.69. Brittle.
BEFORE BLOWPIPE, ETC.—Infusible. Colors borax bead red. In closed tube, ields water. Soluble in warm dilute hydrochloric acid, with effervescence, to a green olution.

GARNIERITE.—Noumeite.

COMPOSITION.—$H_2(Ni.Mg)SiO_4 + H_2O$ or $2(Ni.Mg)_3Si_4O_{13}.3H$

GENERAL DESCRIPTION.—Loosely compacted masses of brilli dark-green to pale-green mineral, somewhat unctuous. Struct often small mammelonated, with dark-green, varnish-like surfac enclosing dull green to yellowish ochreous material. Eas broken and earthy.

Physical Characters. H., 2 to 3. Sp. gr., 2.27 to 2.8.

LUSTRE, varnish-like, to dull. OPAQUE.

STREAK, light green to white. TENACITY, friable

COLOR, deep green to pale greenish-white.

UNCTUOUS, adheres to the tongue.

BEFORE BLOWPIPE, ETC.—Infusible, decrepitates. In closed tu yields water. Colors borax bead red. Partially soluble in hyd chloric and nitric acids.

SIMILAR SPECIES.—Differs from malachite and ch[illegible]ocolla structure and unctuous feeling. Differs from serpentine in de color and nickel reaction.

REMARKS.—Occurs in New Caledonia in veins in serpentine, with chromite talc. Possibly derived from a nickel-bearing chrysolite. Deposits are also know Riddles, Oregon and Webster, N. C.

USES.—It is now the chief source of nickel.

CHAPTER XXIII.

ZINC AND CADMIUM MINERALS.

THE ZINC MINERALS.

THE zinc minerals described are: *Sulphide*—SPHALERITE. *Oxide*—ZINCITE. *Sulphate*—GOSLARITE. *Carbonates*—SMITHSONITE, HYDROZINCITE. *Silicates*—WILLEMITE, CALAMINE.

The important ores of zinc are sphalerite, smithsonite, and calamine; and, in New Jersey, willemite and zincite occur in quantity [illegible] to be considered ores. A large amount of zinc oxide is also made from franklinite which is described under the iron minerals.

In this country, Missouri, Kansas, Indiana and Illinois yield most of the zinc ore, although other important regions are Pennsylvania, New Jersey, and Virginia. The western ore contains lead ore, from which it is separated by concentration. In all, in 1899, this country produced 135,796 tons of metallic zinc and 31,663 tons of zinc oxide were manufactured.*

The principal uses of metallic zinc are in galvanizing iron wire or sheets and in manufacturing brass. A smaller amount is made into sheet zinc and zinc dust.

Metallic zinc is obtained by distillation of its roasted ores with carbon. The sulphide and carbonate, by roasting, are converted into oxide, and the silicates are calcined to remove moisture. The impure oxides, or the silicate, are mixed with fine coal and charged in tubes or vessels of clay, closed at one end and connected at the other end with a condenser. These are submitted to a gradually increasing temperature, by which the ore is reduced to metallic zinc, and, being volatile, distills, and is condensed. Apparently successful processes are now in use for the direct deposition of zinc from its ores by electrolysis.

Zinc oxide, ground in oil, constitutes the paint zinc white. The oxide may be made from the metal by heating it to a temperature

* *Engineering and Mining Journal*, 1900, p. 2.

at which the zinc takes fire and drawing the fumes into suitab condensers; or, as in this country, it may be made directly fro the ore.

SPHALERITE.—Blende, Black Jack.

COMPOSITION.—ZnS, (Zn, 67 per cent.). Often contains C Mn, Fe.

GENERAL DESCRIPTION.—A mineral of resinous lustre shadi in color from yellow through brown to nearly black and more less translucent. It occurs most frequently cleavable massive b also in crystals and in compact fine-grained masses or alterna concentric layers with galenite.

FIG. 422.

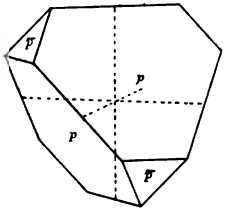


FIG. 423.

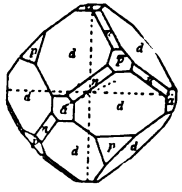
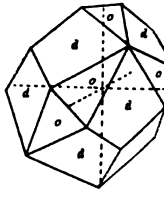


FIG. 424.



CRYSTALLIZATION.—Isometric. Hextetrahedral class p. 18. Usu ally the dodecahedron d with the tetrahedron p and a modifyin tristetrahedron $o = a : 3a : 3a$, Fig. 424, or $n = a : 2a : 2a$, Fi 423. More rarely the + and — tetrahedron, Fig. 422.

Index of refraction for yellow light, 2.3692.

Physical Characters. H., 3.5 to 4. Sp. gr., 3.9 to 4.1.

LUSTRE, resinous. TRANSPARENT to translucent.

STREAK, white to pale brown. TENACITY, brittle.

COLOR, yellow, brown, black; rarely red, green or white.

CLEAVAGE, parallel to rhombic dodecahedron (angles 120° an 90°).

BEFORE BLOWPIPE, ETC.—On charcoal fuses with difficulty, bu readily yields a sublimate, sometimes brown at first from cadmiu and later yellow while hot, white when cold and becoming brigh green if moistened and ignited with cobalt solution. With sod gives a sulphur reaction. Soluble in hydrochloric acid with effer vescence of hydrogen sulphide.

SIMILAR SPECIES.—Smaller crystals sometimes slightly resembl garnet or cassiterite, but are not so hard.

REMARKS.—Sphalerite has probably been formed by precipitation from water b H_2S or with the aid of decaying organic matter. By oxidation it changes to sulphat which in turn may be decomposed by carbonates and silicates forming carbonates an

ilicates of zinc. Sphalerite is a common associate of lead and silver ores and is detimental, as it makes their treatment more difficult. It also occurs with other sulphides nd with other zinc ores. It is mined in southwest Missouri, at Friedensville, Pa., in he southwestern part of Wisconsin, at Pulaski, Va., and at other places. In small uantities it is of very common occurrence.

USES.—It is an important ore of zinc and also is the source of most of the cadmium of commerce.

ZINCITE.—Red Zinc Ore.

COMPOSITION.—ZnO, (Zn 80.3 per cent.) with usually some Mn or Fe.

GENERAL DESCRIPTION.—A deep red to brick-red adamantine mineral occurring in lamellar or granular masses, either in calcite or interspersed with grains and crystals of black franklinite and yellow to green willemite. A few hexagonal pyramids have been found.

Physical Characters. H., 4 to 4.5. Sp. gr., 5.4 to 5.7.

LUSTRE, sub-adamantine. TRANSLUCENT.
STREAK, orange yellow. TENACITY, brittle.
COLOR, deep red to orange red.
CLEAVAGE, basal and prismatic yielding hexagonal plates.

BEFORE BLOWPIPE, ETC.—Infusible. On charcoal gives reactions for zinc as described under sphalerite. In closed tube blackens, but is again red on cooling. With borax usually gives amethystine bead. Soluble in hydrochloric acid without effervescence.

SIMILAR SPECIES.—Differs from realgar and cinnabar in its associates, infusibility and slow volatilization.

REMARKS.—Occurs in quantity only in Sussex County, N. J., at the franklinite localities and is smelted with the associated franklinite, willemite, etc., and the zinc recovered.

GOSLARITE.—Zinc Vitriol.

COMPOSITION.—$ZnSO_4 + 7H_2O$, (ZnO 28.2, SO_3 27.9, H_2O 43.9 per cent.).

GENERAL DESCRIPTION.—A white or yellowish earthy mineral with nauseous astringent taste. Usually an incrustration or mass shaped like the original sphalerite or in stalactites. Rarely needle-like orthorhombic crystals.

PHYSICAL CHARACTERS.—Translucent. Lustre, vitreous to dull. Color, white, yellowish, or bluish. Streak, white. H., 2 to 2.5. Sp. gr., 1.9 to 2.1.

BEFORE BLOWPIPE, ETC.—Fuses easily. Yields water in closed tube. With soda gives a white coat and a sulphur test. Easily soluble in water.

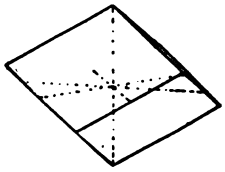
REMARKS.—Goslarite is formed by the oxidation of sphalerite in damp locations.

SMITHSONITE.—Dry Bone, Calamine.

COMPOSITION.—$ZnCO_3$. (ZnO, 64.8; CO_2, 35.2 per cent.).

GENERAL DESCRIPTION.—Essentially a white vitreous mineral but often colored yellowish or brownish by iron. Structure stalactitic or botryoidal, or with drusy crystal surface; also in chalky cavernous masses and granular. Sometimes of marked colors as deep green or bright yellow from copper or cadmium respectively.

FIG. 425.



CRYSTALLIZATION.—Hexagonal. Scalenohedral class p. 39. Axis $\dot{c} = 0.8063$. Usually small rhombohedrons of 107°, Fig. 425, like those of siderite.

Optically —.

Physical Characters. H., 5. Sp. gr., 4.3 to 4.5.

LUSTRE, vitreous to dull. TRANSLUCENT to opaque.

STREAK, white. TENACITY, brittle.

COLOR, shades of white, more rarely yellow, green, blue, etc.

CLEAVAGE, parallel to rhombohedron (107°).

BEFORE BLOWPIPE, ETC.—Infusible but readily yields white sublimate on coal, often preceded by brown of cadmium. The sublimate becomes yellow when heated and becomes bright green when moistened with cobalt solution and then heated. Soluble in acids with effervescence.

SIMILAR SPECIES.—Distinguished from calamine by its effervescence and from other carbonates by its hardness.

REMARKS.—Smithsonite is a secondary product formed usually by action of carbonated waters on other zinc ores and sometimes by atmospheric action. It occurs with the other ores of zinc, especially calamine, and with ores of lead, copper and iron. In this country it is most abundant in the Missouri, Virginia and Wisconsin zinc regions.

USES.—Smithsonite, being easily reduced with little fuel, is a valuable zinc ore, but as it is found chiefly near the surface, the deposits have been nearly exhausted.

HYDROZINCITE.—Zinc Bloom.

COMPOSITION.—$ZnCO_3 \cdot 2Zn(OH)_2$, (ZnO 75.3, CO_2 13.6, H_2O 11.1 per cent.).

GENERAL DESCRIPTION.—Usually a soft white incrustation upon other zinc minerals, or as dazzling white stalactites, or earthy and chalk like.

PHYSICAL CHARACTERS.—Opaque. Lustre, dull or pearly. Color, pure white to yellowish. Streak shining white. H., 2 to 2.5. Sp. gr., 3.58 to 3.8.

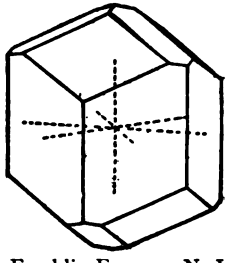
BEFORE BLOWPIPE, ETC.—Infusible. Coats the coal like smithsonite. Yields water in closed tube. Soluble in cold dilute acids with effervescence.

WILLEMITE.—Troostite.

COMPOSITION.—Zn_2SiO_4, (ZnO, 72.9; SiO_2, 27.1); often with much manganese replacing zinc.

GENERAL DESCRIPTION.—A greenish yellow to apple green or sulphur yellow mineral when pure, but often flesh red or brownish from manganese or iron. Usually occurs granular, but also as hexagonal crystals and massive. The New Jersey variety is known by its associates, franklinite and zincite.

FIG. 426.



Franklin Furnace, N. J.

CRYSTALLIZATION.—Hexagonal. Class of third order rhombohedron p. 46. Axis $\dot{c}$ = 0.6775. Long slender prisms of yellowish color and coarse thick prisms of flesh red color occur at Franklin Furnace; the Altenberg crystals are small and brown in color.

Physical Characters. H., 5.5. Sp. gr., 3.89 to 4.2.

LUSTRE, resinous. TRANSPARENT to opaque.

STREAK, nearly white. TENACITY, brittle.

COLOR, greenish to sulphur yellow, apple green, white, flesh red.

CLEAVAGE, basal and prismatic.

BEFORE BLOWPIPE, ETC.—Fusible in thin splinters only upon the edges to a white enamel. On charcoal with soda and a little borax yields the zinc coat. Soluble in hydrochloric acid leaving a gelatinous residue.

SIMILAR SPECIES.—Red crystals resemble apatite but differ in terminations, rhombohedral in willemite but pyramidal in apatite. Willemite is also heavier than apatite and gelatinizes.

USES.—In association with the other minerals of Franklin, N. J., it constitutes a valuable ore of zinc. This, however, is its only important locality.

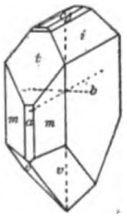
CALAMINE.—Electric Calamine.

COMPOSITION.—$(ZnOH)_2SiO_3$, (ZnO, 67.5; SiO_2, 25.0; H_2O, 7.5 per cent.).

GENERAL DESCRIPTION.—A white or brownish white vitreo mineral frequently with a drusy surface or in radiated groups crystals, the free ends of which form a ridge or cockscomb, F 428 and, more rarely, small distinct transparent crystals. It c curs also granular, stalactitic, botryoidal and as a constituent clay.

CRYSTALLIZATION.—Orthorhombic. Hemimorphic class p. 5 Axes $\breve{a} : \breve{b} : \dot{c} = 0.783 : 1 : 0.478$. The crystals are usually tabul

FIG. 427.



Altenberg.

FIG. 428.

Sterling Hill, N. J.

the broad face being the brachy pinacoid b while the prism m relatively small. v is the pyramid $2\breve{a} : \breve{b} : 2c$.

Angles are: $mm = 103° 51'$; $ct = 118° 49'$; $ii = 69° 48'$; $= 101° 34'$

Optically +, with acute bisectrix vertical. $2E$ for yellow lig $= 78° 39'$

Physical Characters. H., 4.5 to 5. Sp. gr., 3.4 to 3.5.

LUSTRE, vitreous to pearly. OPAQUE to transparent.

STREAK, white. TENACITY, brittle.

COLOR, yellow to brown, white, colorless, rarely blue or green

Cleavage, prismatic.

BEFORE BLOWPIPE, ETC.—Fusible only in finest splinters. Wit soda and borax, on charcoal yields a white coating, which is mad bright green by heating with cobalt solution. In closed tub yields water. With acids, dissolves, leaving a gelatinous residu

SIMILAR SPECIES.—It is softer than prehnite, harder than cerus site, and gelatinizes with acids. It differs from willemite in wate reaction, and from stilbite in difficulty of fusion.

REMARKS.—Calamine seems to be formed by the action of hot silica bearing wate upon other zinc ores, especially sphalerite. It is often disseminated through a cla from which it is gradually segregated and crystallized. Its most important locality

America is at Granby, Mo. It is also found in quantity at Sterling Hill, N. J., and Bertha, Va. Abroad, it is exported from Greece, and is mined in large amounts in Silesia and the Rhenish Provinces of Germany.

USES.—It is a valuable ore of zinc, usually free from volatile impurities.

THE CADMIUM MINERALS.

The only cadmium mineral is the *Sulphide*, GREENOCKITE.

About five tons per year of cadmium are obtained from the Silesian zinc ores. The first fumes are redistilled and finally reduced with carbon. The metal is used in fusible alloys and certain forms of silver plating. The sulphide forms a splendid yellow pigment unaltered by exposure.

GREENOCKITE.

COMPOSITION.—CdS, (Cd, 77.7 per cent.)

GENERAL DESCRIPTION.—Usually a bright yellow powder upon sphalerite, or a yellow coloration *in* smithsonite. Very rarely as small hemimorphic hexagonal crystals. $\dot{c} = 0.8111$.

PHYSICAL CHARACTERS.—Translucent. Lustre earthy or adamantine. Color yellow to orange yellow or bronze yellow. Streak orange yellow. H., 3 to 3.5. Sp. gr., 4.9 to 5.0.

BEFORE BLOWPIPE, ETC.—Infusible, but is easily volatilized in the reducing flame, coating the coal with a characteristic brown coat and a iridescent tarnish. In closed tube, turns carmine red on heating, but is yellow on cooling. Soluble in strong hydrochloric acid, with effervescence of hydrogen sulphide.

CHAPTER XXIV.

TIN, TITANIUM, AND THORIUM MINERALS.

THE TIN MINERALS.

The minerals described are: *Sulphide*, STANNITE; *Oxide*, CASSITERITE. Tin is also found as an occasional constituent of tantalite and other tantalates.

Cassiterite is the only ore of tin, and while it occurs or has been reported from nine or ten states, no tin is now produced* in the country. The world's supply of tin, amounting yearly to about 80,000 long tons, comes chiefly from the East India Islands, Tasmania, Bolivia and Cornwall, England.

The principal use of tin is for the manufacture of tin plate—sheet-iron coated with tin—which is used for canning purposes and in household utensils, etc. It is also largely used in alloys such as bronze, bell metal, pewter, solder and tin amalgam. Tin foil is also made from it.

The ore as mined is first separated from gangue and impurities by washing, jigging, etc., and if necessary, is then calcined or roasted, to remove volatile elements, such as sulphur, arsenic, antimony.

The concentrated and purified ore may then be smelted with carbon in a shaft furnace. The modern practice is, however, to smelt the ore for several hours in a reverberatory furnace with coal. The liquid tin is drawn off in a float and the slags are resmelted at a higher temperature, frequently requiring the addition of iron or of lime to aid in the separation of the tin, which they still contain. The impure metal obtained is slowly heated to a temperature but little above the melting point of tin; comparatively pure tin separates and this is further purified by oxidation. This oxidation is accomplished either by forcing green wood under the liquid metal causing violent agitation or by repeatedly pouring the melted tin in a thin stream from ladles. Tin may also be refined by electrolysis.

*The Temescal mines of California produced about 120 tons from 1890 to 1892 but have since been unproductive.

STANNITE.—Tin Pyrites.

COMPOSITION.—(Cu.Sn.Fe)S. Uncertain.

GENERAL DESCRIPTION.—A massive, granular mineral, of metallic lustre and steel-gray color. It is often intermixed with the yellow chalcopyrite.

PHYSICAL CHARACTERS.—Opaque. Lustre metallic. Color steel gray to nearly black. Streak black. H = 4. Sp. gr., 4.5 to 4.52. Brittle.

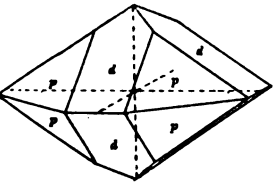
BEFORE BLOWPIPE, ETC.—In the reducing flame fuses. In the oxidizing flame yields SO_2, and is covered by white oxide, which becomes bluish green when heated with cobalt solution. Soluble in nitric acid to a green solution, with separation of sulphur and oxide of tin. With soda, gives sulphur reaction.

CASSITERITE.—Stream Tin. Tin Stone.

COMPOSITION.—SnO_2, (Sn 78.6 per cent.), and usually with some Fe_2O_3, and sometimes Ta_2O_5, As_2O_5, SiO_2 or Mn_2O_3.

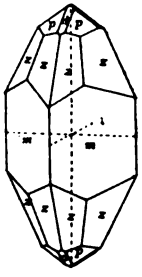
GENERAL DESCRIPTION.—A hard and heavy brown to black mineral occurring either in brilliant adamantine crystals or more frequently in dull botryoidal and kidney-shaped masses and rounded pebbles, often with a concentric or fibrous radiated structure.

FIG. 429.



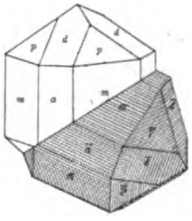
Stoneham, Me.

FIG. 430.



Cornwall, Eng.

FIG. 431.



Zinnwald.

CRYSTALLIZATION.—Tetragonal. Axis $\dot{c} = 0.672$. Common forms are the unit first and second order pyramids and prisms p, a, m, and d, and the ditetragonal pyramid $z = a : \frac{3}{2}a : 3c$. Angles $pp = 121° 41'$; $dd = 133° 32'$; $mz = 155° 1'$.

Frequently twinned parallel to the second order pyramid, Fig. 431.

Optically + with high indices of refraction 1.996 and 2.093.

Physical Characters. H., 6 to 7. Sp. gr., 6.8 to 7.1.

LUSTRE, adamantine to dull. OPAQUE to translucent.

STREAK, white or pale brown. TENACITY, brittle.

COLOR, brown to nearly black, sometimes red, gray, or yellow.

CLEAVAGES, indistinct pyramidal and prismatic.

BEFORE BLOWPIPE, ETC.—Infusible, but in powder becomes y low and luminous. With cobalt solution the powder or any su limate is made bluish green. On charcoal with soda may be duced, yielding metallic button and a faint white sublimate close the assay. Insoluble in acids and almost so in salt of phospho or borax in which it usually gives some manganese or iron reacti

VARIETIES.

Tin Stone.—Crystals and granular masses.

Wood Tin.—Masses with concentric structure, the zones bei of different color and internally fibrous.

Stream Tin.—Rounded pebbles and grains found in alluvial posits.

SIMILAR SPECIES.—The high specific gravity distinguishes it fr silicates which it resembles, and the infusibility and insolubil distinguish it from wolframite, etc.

REMARKS.—Cassiterite is found in veins in granite, gneiss, mica, schist and sim rocks with quartz, wolframite and scheelite, and also with certain sulphides and oxi It occurs also in alluvial deposits, as stream tin. It is practically unchanged by atm pheric influences. The East Indian settlements of Malacca, Banca and Bilitong the greatest producers of tin ore. They are closely followed by the mines in N South Wales, Queensland and Tasmania. Tin is also mined in large quantities at the cient localities in Cornwall, England. In America the chief localities are in the Har Peak region in South Dakota; near Temescal, California, and at Durango, Mex It has been found also in New Hampshire, Virginia, Maine, Massachusetts, Alaba Wyoming and Montana but has not yet been obtained from any American locality quantity sufficient to be called important.

USES.—All tin is made from cassiterite. The artificial oxide used as a polishing powder.

THE TITANIUM MINERALS.

The minerals described are: *Oxides*—RUTILE, OCTAHEDRI and BROOKITE. Titanium is also a constituent of ilmenite, a titanite, elsewhere described, and occurs in some other miner

Oxide of titanium is used to impart an ivory-like appearance porcelain, but otherwise is of no commercial importance. A hundred pounds (6150 pounds between 1880 and 1890) are m keted each year in the United States.

The metal is only produced as a chemical curiosity or for study of its properties. It is prepared by the reduction of oxide by carbon at the highest available temperature of the elec

rnace. In the form thus obtained it carries a small percentage of arbon, is the most infusible of metals and almost equals the dia-ond in hardness.

RUTILE.—Nigrine.

COMPOSITION.—TiO_2, (Ti 61 per cent.).

GENERAL DESCRIPTION.—Brownish red to nearly black prismatic rystals often included in other minerals in hair-like or needle-ke penetrations. Also coarse crystals embedded in quartz, eldspar, etc., or in parallel and crossed and netted needles upon ematite or magnetite. Occasionally massive when black and iron earing.

FIG. 432.

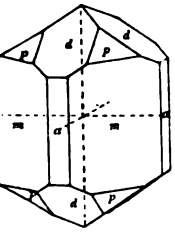
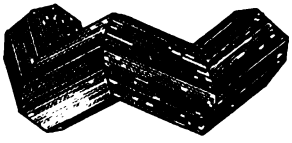


FIG. 433.

Magnet Cove, Ark.

FIG. 434.



CRYSTALLIZATION.—Tetragonal. Axis $\dot{c} = 0.644$. Very close o cassiterite in angle and form. Usual combinations are unit first nd second order pyramids p and d and first and second order risms m and a. Often twinned in knees, Fig. 434, and rosettes, ig. 433. Prisms often striated vertically.

Angles $pp = 123° 7\frac{1}{2}'$; $dd = 134° 58'$.

Optically + with very high indices of refraction 2.616 and 2.902 or yellow light.

Physical Characters. H., 6 to 6.5., Sp. gr., 4.15 to 4.25.

LUSTRE, adamantine to nearly metallic. OPAQUE to transparent.

STREAK, white, pale brown. TENACITY, brittle.

COLOR, reddish brown, red, black. Deep red when transparent.

CLEAVAGES; prismatic and pyramidal.

BEFORE BLOWPIPE, ETC.—Infusible. In salt of phosphorus issolves *very* slowly in the oxidizing flame to a yellow bead hich becomes violet in the reducing flame. Insoluble in acids.

SIMILAR SPECIES.—It is redder and of lower specific gravity than assiterite. The nearly metallic lustre, weight and infusibility eparate it from garnet, tourmaline, vesuvianite, pyroxene, etc.

REMARKS.—Widely distributed and associated with many minerals in which usually embedded. Little altered by atmospheric influences. Found in many A can localities; prominent among them are Lincoln County, Ga., Habersham C Ga., Warwick, N. Y., Warren, Me. and Magnet Cove, Ark.

USES.—Rutile is used to color porcelain yellow and to give desired bluish white tint to artificial teeth.

OCTAHEDRITE.—Anatase.

COMPOSITION.—TiO_2.

GENERAL DESCRIPTION.—Very bright brown, deep steely blue and black pyr crystals, sometimes acute and sometimes obtuse but always small.

FIG. 435.

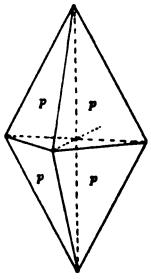
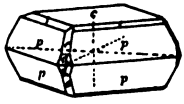


FIG. 436.



CRYSTALLIZATION.—Tetragonal. Axis $\dot{c} = 1.777$. Angles $pp = 97° 51'$, $111° 42'$.

Optically —.

PHYSICAL CHARACTERS.—Transparent to opaque. Lustre, metallic or adama Color, brown, indigo blue, black. Streak, white. H., 5.5 to 6. Sp. gr., 3.82 to Brittle. Cleavage, pyramidal and basal.

BEFORE BLOWPIPE, ETC.—As for rutile.

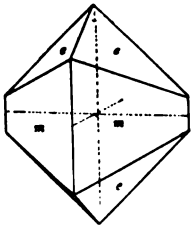
REMARKS.—After heating the specific gravity becomes 4.11 to 4.16 or about th rutile.

BROOKITE.

COMPOSITION.—TiO_2.

GENERAL DESCRIPTION.—Either brown translucent crystals which are thi tabular, or black opaque crystals of varied habit.

FIG. 437.



Magnet Cove, Ark.

FIG. 438.

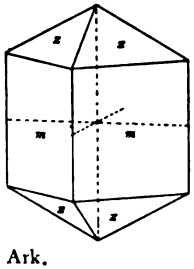
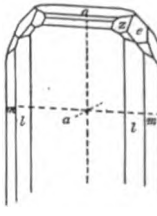


FIG. 439.



Ellenville, N. Y

CRYSTALLIZATION.—Orthorhombic. Axes $\dot{a} : \bar{b} : \dot{c} = 0.842 : 1 : 0.944$. Co forms: unit prism m with pyramids $z = \dot{a} : \bar{b} : \frac{1}{2}c$ or $e = 2\dot{a} : \bar{b} : c$.

Angles $mm = 99° 50'$. $zz = 135° 14'$. $ee = 101° 3'$.

Optically + with acute bisectrix always normal to face *a* but plane of optic axes *c* for red and yellow and *b* for blue giving characteristic interference figure in white light.

PHYSICAL CHARACTERS.—Translucent to opaque. Lustre, submetallic to adamantine. Color, brown, yellow or black. Streak, white or yellow. H., 5.5 to 6. Sp. gr., 3.87 to 4.01. Cleavage, indistinct prismatic and basal.

BEFORE BLOWPIPE, ETC.—As for rutile and octahedrite.

THE THORIUM MINERALS.

The minerals described are: *Phosphate* (of cerium) MONAZITE; *Silicate*, THORITE. The production of monazite sand in North Carolina has greatly decreased owing to the fact that deposits have been found in Brazil which can be had for the cost of government taxes and the labor of loading into ships. The sand occurs there in immense deposits, certain beaches consisting of 90 % of monazite. The production of the United States in 1898 was 150,000 pounds.*

The oxide of thorium has become exceedingly important of late years through its property of emiting an intense white light when held in the flame of a Bunsen gas burner.

The mantle of the Welsbach incandescent gas lamp consists of about 99 % of thorium oxide with one per cent. of cerium oxide. The price of thoria has recently been greatly reduced owing to competition and improved methods of production and to the low price of Brazilian monazite.

The chief source of thoria is the phosphate of cerium mineral, monazite. This mineral carries salts of thorium as impurities and in quantities varying from traces to as much as 18.5 % of thorium oxide. The mineral thorite is also employed in the production of thoria, but, although it contains over 20 % of the oxide, it is much more difficult to obtain in quantity.

Thoria is manufactured by methods which are generally carefully guarded. A recent authority † states that the method usually employed is to decompose the monazite sand in hot sulphuric acid. The sulphates are converted into oxalates from which the thorium oxalate is separated by means of ammonium oxalate, and afterwards transformed into thorium nitrate which on heating yields the oxide.

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* *Mineral Industry*, Vol. VII., 1899, p. 517.

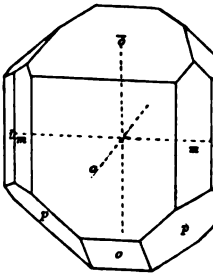
† Prof. L. M. Dennis, *Mineral Industry*, Vol. VI., p. 489.

MONAZITE.

COMPOSITION.—(Ce.La.Di)PO_4, but with notable quantities thorium and silicon and frequently small amounts of erbium ytterbium.

GENERAL DESCRIPTION.—Small, brown, resinous crystals, or yellow, translucent grains, disseminated or as sand. Sometimes in angular masses.

FIG. 440.



CRYSTALLIZATION.—Monoclinic. Axes $\dot{a} : \bar{b} : \dot{c} = 0.969 : 1 : 0.926$; $\beta = 76° 20'$. Crystals are usually small and flat, but sometimes large. Fig. 440 shows the pinacoids *a* and *b*, the unit pyramid, prism and dome *p*, *m* and *o* and the prism $l = 2a : b : \infty c$. Angles $mm = 93° 2$ $a\bar{o} = 140° 48'$, $pp = 106° 41'$.

OPTICALLY +, with axial plane nearly *a* and acute bisect nearly vertical. Axial angle in red light $2E = 29°$ to $31°$.

Physical Characters. H., 5–5.5. Sp. gr. 4.9–5.3.

LUSTRE, resinous. OPAQUE, to translucent.

STREAK, white. TENACITY, brittle.

COLOR, clove brown, reddish brown, yellow.

CLEAVAGE, basal, perfect.

BEFORE BLOWPIPE, ETC. Turns gray when heated, but does fuse. Is decomposed by hydrochloric acid with a white resid Solutions added to a nitric acid solution of ammonium molybd produce a yellow precipitate.

REMARKS.—Monazite is found in considerable quantities in North and South C lina, as sand and as a rock constituent. The Brazilian sand which is now the c source of supply is found at Bahia, Minas Geraes, Caravellas, San Pedro and Antig

USES.—It is the chief source of the thoria used in mantles for candescent gas lighting. It is also the chief source of the r elements cerium, lanthanum and didymium.

THORITE.—Orangite.

COMPOSITION.—$ThSiO_4$, carrying some water.

GENERAL DESCRIPTION.—Black or orange yellow tetragonal crystals like thos zircon. Also found massive.

PHYSICAL CHARACTERS.—Translucent to transparent, lustre, resinous, color, bl brown and orange. Streak, orange to brown. Brittle. H., 4.5–5. Sp. gr. 4.8–

BEFORE BLOWPIPE, ETC.—Infusible. Gelatinizes with hydrochloric acid be being heated by blowpipe but not after. In closed tube yields water and the ora variety becomes nearly black while hot, but changes to orange again on cooling.

REMARKS.—Occurs chiefly in Norway.

USES.—Is a source of thoria, but less important than monazite.

CHAPTER XXV.

LEAD AND BISMUTH MINERALS.

THE LEAD MINERALS.

The minerals described are: *Metal*, LEAD; *Sulphides and Selenides*, GALENITE, BOURNONITE, JAMESONITE, CLAUSTHALITE; *Oxides*, MINIUM; *Sulphates*, ANGLESITE, LINARITE; *Phosphate*, PYROMORPHITE; *Arsenate*, MIMETITE; *Carbonates*, CERUSSITE and PHOSGENITE; *Chromate*, CROCOITE; *Vanadates*, VANADINITE, DESCLOIZITE; *Molybdate*, WULFENITE; *Tungstate*, STOLZITE.

The most important ores of lead are galenite and cerussite.

The world uses nearly 800,000 tons of lead per year, of which this country, in 1899, produced 213,003 tons.* Of this about one-quarter was soft lead, mainly produced in Missouri and Kansas, containing almost no silver and gold. During the same year one half of the total output of lead was desilverized; indeed, it may be said that by far the most important use of lead ore is to mix and smelt with silver ores whereby metallic lead containing silver and gold is obtained.

The principal use of metallic lead is in the manufacture of white lead, 103,282 tons being produced in 1899 in the United States alone. Large amounts are also used for the preparation of red lead, litharge, shot, lead pipe and sheet lead. A certain amount of lead containing antimony is used in type and in alloys for friction-bearings.

The argentiferous lead ores of the west, which ordinarily run low in lead are smelted in blast-furnaces. The ore, if it contains much sulphur, is roasted, to remove the sulphur and other volatile constituents, and is then fused, forming a silicate, which is charged in the furnace with the proper proportions of fuel and flux (limestone, hematite, etc.). The reduction takes place under the action of the blast. Metallic lead, carrying most of the silver, is produced, and if either sulphur or arsenic is present, a sulphide (matte)

* *Engineering and Mining Journal*, 1900, p. 2.

and an arsenide (speiss) of iron, copper, etc., will form, and al all these will float the slag composed of the gangue and the f

The furnace is usually oblong in section, and the hearth is nected, by a channel from the bottom, with an outer basin or so that the metal stands at the same level in each and can ea be ladled out. Above the hearth, and enclosing the smelting z are what are called the water-jackets, in which cold water culates. The furnace gases pass through a series of conden chambers.

The matte, speiss and the dust collected in the condensing ch bers are all treated for silver, gold, lead, copper, etc., usuall different works. The metallic lead, or base bullion, is desilver by remelting in large kettles, raising it to the melting-point of adding metallic zinc and cooling to a point between the melt points of zinc and lead. The lighter solidified zinc separates, *ca ing with it the silver*, and forms a crust on the surface of the l from which it is skimmed.

The lead is further purified and the zinc and silver separa electrolytically or by distillation.

LEAD.—Native Lead.

COMPOSITION.—Pb, with sometimes a little Sb or Ag.

GENERAL DESCRIPTION.—Usually small plates or scales or globular masses bedded in other minerals. Very rarely in octahedrons or dodecahedrons.

PHYSICAL CHARACTERS.—Opaque. Lustre metallic. Color and streak lead H., 1.5. Sp. gr., 11.37. Malleable.

BEFORE BLOWPIPE, ETC.—Fuses easily, coating charcoal with yellow oxide, tinging flame light blue. Soluble in dilute nitric acid.

GALENITE.—Galena.

COMPOSITION.—PbS, (Pb 86.6 per cent.) usually with some sil and frequently sulphide of antimony, bismuth, cadmium, etc.

FIG. 441.

Joplin, Mo.

GENERAL DESCRIPTI —A soft, heavy, lead-g mineral, with metallic l tre and easy cubical cle age. Sometimes in cr tals. Rarely fine-grai or fibrous.

CRYSTALLIZATION.—I metric. Usually the cu *a* or cubo-octahedron *a p*, sometimes octahedral or show

that rare form the trigonal trisoctahedron $r = a : a : 2a$, Fig. 444. Sometimes twinned or in skeleton crystals or reticulated.

FIG. 442.

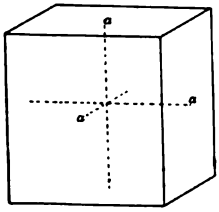


FIG. 443.

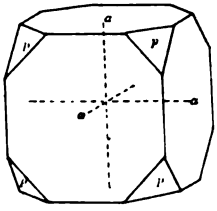
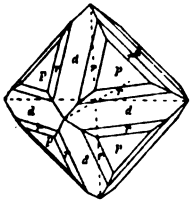


FIG. 444.



Physical Characters.—H., 2.5. Sp. gr., 7.4 to 7.6.

LUSTRE, metallic.
STREAK, lead-gray.
COLOR, lead-gray.
OPAQUE.
TENACITY, brittle.
CLEAVAGE, cubic, very easy.

BEFORE BLOWPIPE, ETC.—On charcoal decrepitates and fuses easily, yielding in O. F. a white sulphate coat, and in R. F. a yellow coat and metallic button of lead. With bismuth flux, gives a strong iodide coat, which appears chrome-yellow on plaster and greenish-yellow on charcoal. With soda, yields malleable lead and a sulphur test. Soluble in excess of hot hydrochloric acid, from which white lead chloride separates on cooling. Soluble also in strong nitric acid, with separation of sulphur and lead sulphate.

SIMILAR SPECIES.—Characterized by its cleavage, weight and appearance, except in some fine-grained varieties.

REMARKS.—Galenite is the common and parent ore of lead. It occurs with other sulphides, especially sphalerite, pyrite and chalcopyrite, with a gangue of quartz, fluorite, barite or calcite. Also with ores of silver and gold. It changes easily to cerussite, anglesite and other lead minerals. Besides the silver-producing States of Colorado, Utah and Montana, which also produce the most lead, Kansas, Wisconsin and Missouri manufacture much soft lead from their deposits of galenite.

USES.—It is the chief ore of lead, and as it usually contains silver, the silver-bearing deposits are more frequently worked than the purer galenite, and both the lead and silver are recovered.

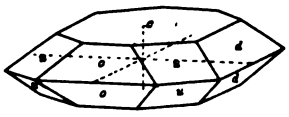
BOURNONITE.

COMPOSITION.—$PbCuSbS_3$, (Pb 42.5, Cu 13.0, Sb 24.7, S 19.8 per cent.).

GENERAL DESCRIPTION.—A gray metallic mineral, nearer steel-gray than galenite, and occurring fine-grained, massive and in thick tabular crystals. More like tetrahedrite than galenite when massive.

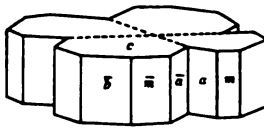
CRYSTALLIZATION.—Orthorhombic. Axes $\breve{a} : \dot{b} : \dot{c} = 0.938 : 1 : 0.897$. C forms the pinacoids *a*, *b*, *c*, the unit domes and prism *d*, *o*, and *m*, and the pyramid *b* : ½ *c*. Short prismatic or tabular, with vertically striated faces, or, in cross, Fi and "cog-wheel" twins. Angles $m\,m = 93°\ 40'$, $c\,o = 136°\ 17'$, $c\,u = 146°$

FIG. 445.



Harz.

FIG. 446.



Kapnik.

PHYSICAL CHARACTERS.—Opaque. Lustre, metallic. Color, steel-gray to black. Streak, steel-gray. H., 2.5 to 3. Sp. gr., 5.7 to 5.9. Brittle. Cleavag perfect.

BEFORE BLOWPIPE, ETC.—On charcoal, fuses easily, yielding heavy white subl and later a yellow sublimate. With bismuth flux yields strong greenish-yellow c charcoal and a mingling of chrome yellow and peach red on plaster. After subl have formed, the residue will color the flame deep green, or if moistened with of hydrochloric acid, will color the flame bright azure blue. Soluble in nitri to a green solution, with formation of a white insoluble residue.

JAMESONITE.—Feather Ore.

COMPOSITION.—$Pb_2Sb_2S_5$. (Pb 50.8, Sb 29.5, S 19.7 per cent.).

GENERAL DESCRIPTION.—Steel-gray to dark-gray metallic needle crystals, o like and felted; also compact and fibrous massive.

PHYSICAL CHARACTERS.—Opaque. Lustre, metallic. Color, steel-gray to lead gray. Streak, grayish-black. H., 2 to 3; Sp. gr., 5.5 to 6. Brittle.

BEFORE BLOWPIPE, ETC.—Decrepitates and fuses very easily, and is volat coating the charcoal white and yellow as in bournonite. With bismuth flux, reac bournonite. In closed tube, yields dark-red sublimate, nearly black while hot. S in hot hydrochloric acid, with effervescence of hydrogen sulphide.

CLAUSTHALITE.

COMPOSITION.—PbSe, (Pb 72.4, Se 27.6 per cent.). May contain silver or c

GENERAL DESCRIPTION.—Bluish gray fine granular masses of metallic Rarely foliated. Resembles galenite.

PHYSICAL CHARACTERS.—Opaque. Lustre, metallic. Color, bluish lead Streak, grayish black. H., 2.5 to 3. Sp. gr., 7.6 to 8.8.

BEFORE BLOWPIPE, ETC.—On charcoal fuses and yields odor like decayed radish, coats the charcoal with a white sublimate with red border, and later a y coat forms. In open tube gives a red sublimate. With soda yields a mass blackens silver.

MINIUM.

COMPOSITION.—Pb_3O_4. (Pb 90.6 per cent.).

GENERAL DESCRIPTION.—A vivid red powder or loosely compacted mass of d greasy lustre. Often intermixed with yellow.

PHYSICAL CHARACTERS.—Opaque. Bright red. Lustre, dull or greasy. S orange yellow. H., 2 to 3. Sp. gr., 4.6.

BEFORE BLOWPIPE, ETC.—Is reduced to metallic lead, and yields the characteristic lead sublimates.

REMARKS.—The artificial product is the red lead of commerce.

ANGLESITE.

COMPOSITION.—$PbSO_4$, (PbO 73.6, SO_3 26.4 per cent.).

GENERAL DESCRIPTION.—A very brittle, colorless or white mineral of adamantine lustre, sometimes colored by impurities. Usually massive, frequently in concentric layers around a core of unaltered galenite.

FIG. 447.

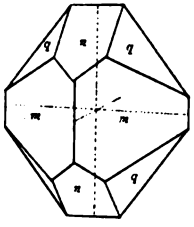
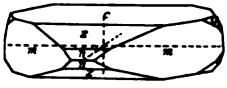


FIG. 448.



Phoenixville, Pa.

CRYSTALLIZATION.—Orthorhombic. Axes $\dot{a} : b : \dot{c} = 0.785 : 1 : 1.289$. Crystals vary greatly in type, but are rarely twinned. Unit prism m and domes such as $n = a : \infty b : \frac{1}{2}c$, $z = a : \infty b : \frac{1}{4}c$ and pyramids $q = 2a : b : c$ are frequent.

Angles: $mm = 103° 43\frac{1}{2}'$; $cn = 146° 36\frac{1}{2}'$; $cz = 157° 41'$; $cq = 123° 12'$.

Optically +, with high indices of refraction 1.877, 1.882 and 1.893 for yellow light. Axial plane is the brachy pinacoid b.

Physical Characters. H., 3. Sp. gr., 6.12 to 6.39.

LUSTRE, adamantine to vitreous. TRANSPARENT to opaque.

STREAK, white. TENACITY, very brittle.

COLOR, colorless, white, gray; rarely yellow, blue or green.

CLEAVAGE, basal and prismatic (90° and 103° 43′).

BEFORE BLOWPIPE, ETC.—On charcoal decrepitates and fuses easily to a glassy globule pearly white on cooling. In R. F. is reduced and yields metallic lead and the yellow sublimate. With soda yields the sulphur reaction. Insoluble in hydrochloric acid but is converted into chloride. Slowly soluble in nitric acid.

SIMILAR SPECIES.—It differs from the carbonate, cerussite, in absence of twinned crystals and of effervescence in acids. It is heavier than barite and celestite, and yields lead.

REMARKS.—Anglesite is formed by the oxidation of galenite. It alters to the carbonate, cerussite, by interchange with calcium carbonate in solution. It is found throughout the United States wherever exposed deposits of galenite occur. The lead mines of Missouri, Wisconsin, Colorado, etc., all contain this mineral. It occurs in large quantities in Mexico and Australia.

USES.—It is an ore of lead.

LINARITE.

COMPOSITION.—$[(Pb.\ Cu)OH]_2SO_4$, (PbO 55.7, CuO 19.8, SO_3 20.0, H_2O 4.5 per cent.).

GENERAL DESCRIPTION.—Small deep blue translucent crystals. Often tabular. Monoclinic.

PHYSICAL CHARACTERS.—Translucent. Lustre, vitreous or adamantine. Color, deep azure blue. Streak, pale blue. H., 2.5. Sp. gr., 5.3 to 5.45. Brittle. Cleavages at 77° to each other.

BEFORE BLOWPIPE, ETC.—Loses color and fuses easily to a pearly glass. In R. F. is reduced to metal yielding yellow coat and ultimately red button, which when moistened with hydrochloric acid will color flame deep blue. Soluble in nitric acid with separation of lead sulphate.

PYROMORPHITE.

COMPOSITION.—$3Pb_4(PO_4)_3.PbCl_2$(PbO 82.2, P_2O_5 15.7, Cl 2.6 per cent.) often with some As, Fe or Ca.

GENERAL DESCRIPTION.—Short hexagonal prisms and branching and tapering groups of prisms in parallel position. The color is most frequently green, brown, or gray. Also in moss-like interlaced fibres and masses of imperfectly developed crystals. Less frequently in globular and reniform masses.

449.

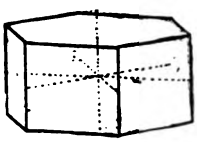


FIG. 450.

Oberlahnstein.

CRYSTALLIZATION.—Hexagonal Class of third order pyramid, p. 37. Axis $\dot{c} = 0.736$. Usual form prism m and base c. Faces m horizontally striated, sometimes tapering.

Physical Characters. H., 3.5 to 4. Sp. gr., 5.9 to 7.1.
LUSTRE, resinous. TRANSLUCENT to opaque.
STREAK, white to pale yellow. TENACITY, brittle.
COLOR, green, gray, brown; also yellow, orange, white.

BEFORE BLOWPIPE, ETC.—On charcoal fuses to a globule which on cooling does not retain its globular form but crystallizes, showing plane faces. In reducing flame yields white coat at a distance and yellow coat nearer the assay, and a brittle globule of lead. In closed tube with magnesium ribbon yields a phosphide which, moistened with water, evolves phosphine. With salt of phosphorus saturated with copper oxide yields an azure blue flame. Soluble in nitric acid, and from the solution ammonium molybdate throws down a yellow precipitate.

SIMILAR SPECIES.—Differs from other lead minerals in fusing to a crystalline globule without reduction.

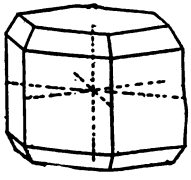
REMARKS.—Probably formed from galenite. Occurs with other lead minerals. Found at Phœnixville, Pa., Davidson county, N. C., Lenox, Me., and many other localities.

MIMETITE.

COMPOSITION.—$3Pb_3(AsO_4)_2 + PbCl_2$ or $Pb_5Cl(AsO_4)_3$, (PbO 74.9, As_2O_5 23.2, Cl 2.39 per cent.), often with some replacement by P or Ca.

GENERAL DESCRIPTION.—Pale yellow to brown hexagonal prisms or globular groups of crystals. Sometimes incrusting.

FIG. 451.



PHYSICAL CHARACTERS.—Translucent. Lustre, resinous. Color, yellow, brown or white. Streak, white. H., 3.5. Sp. Gr., 7.0 to 7.25, lower when Ca is present.

BEFORE BLOWPIPE, ETC.—On charcoal fuses easily and is reduced to metallic lead, coating the coal with white and yellow sublimates and yielding strong arsenical odor. Phosphorus, if present, and chlorine may be detected as in pyromorphite.

CERUSSITE.—White Lead Ore.

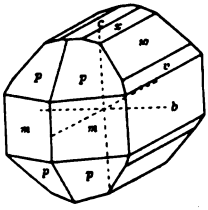
COMPOSITION.—$PbCO_3$, (PbO, 83.5; CO_2, 16.5 per cent.). Often carries silver.

GENERAL DESCRIPTION.—Very brittle, white or colorless orthorhombic crystals; silky, milk-white masses of interlaced fibres; granular, translucent, gray masses and compact or earthy, opaque masses of yellow, brown, etc., colors.

CRYSTALLIZATION.—Orthorhombic. Axes $\dot{a} : \dot{b} : \dot{c} = 0.610 : 1 : 0.723$. Common forms: unit pyramid p, and prism m and a series

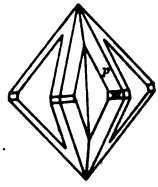
of brachy domes such as $x = \infty \breve{a} : b : \frac{1}{2}c$, $w = \infty \breve{a} : \bar{b} : 2c$ $v = \infty \breve{a} : b : 3c$. Frequently twinned about m sometimes yi ing six rayed groups as in Fig. 453. Common angles are mm 117° 14′, $pp = 130°$, $ww = 69°$ 20′.

FIG. 452.



Black Hawk, Mont.

FIG. 453.



Transbaikal.

Optically —. Axial plane b and acute bisectrix normal t High indices of refraction: 1.804, 2.076, 2.078 in yellow light

Physical Characters. H., 3 to 3.5. Sp. gr., 6.46 to 6.51.

LUSTRE, adamantine, pearly, sometimes silky. TRANSPARENT or translucent

STREAK, white. TENACITY, very brittle.

COLOR, white, gray, colorless or colored by impurities.

CLEAVAGES, parallel to prism and brachy dome.

BEFORE BLOWPIPE, ETC.—On charcoal, decrepitates, fuses a gives a yellow coating, and finally a metallic globule. In clos tube, turns yellow, then dark, and on cooling is yellow. Eff vesces in acids, but with hydrochloric or sulphuric acid leaves white residue.

SIMILAR SPECIES.—Distinguished from anglesite by efferv cence in acids and by frequent occurrence of twinned crysta Has higher specific gravity than most carbonates.

REMARKS.—Cerussite is derived from galenite by the action of water contain carbon dioxide. It may also be produced from anglesite by action of a solution calcium carbonate.

USES.—It is smelted for lead and silver, and a process exists the direct manufacture of white lead from cerussite.

PHOSGENITE.

COMPOSITION.—$Pb_2Cl_2CO_3$, (PbO, 81.9; Cl, 13.0; CO_2, 8.1 per cent.).

GENERAL DESCRIPTION.—Large and small tetragonal crystals, usually prism and colorless; sometimes gray and translucent.

PHYSICAL CHARACTERS.—Transparent to translucent. Lustre, adamantine. Color, colorless, white, gray or yellow. Streak, white. H., 3. Sp. gr., 6 to 6.1. Cleaves parallel to both prisms and the base.

BEFORE BLOWPIPE, ETC.—Fuses easily to a yellow globule. On charcoal, is reduced to metal and forms chiefly a white coating of lead chloride. Soluble in nitric acid with effervescence.

CROCOITE.

COMPOSITION.—$PbCrO_4$, (PbO, 68.9; CrO_3, 31.1 per cent.).

GENERAL DESCRIPTION.—Bright hyacinth-red mineral, usually in monoclinic prismatic crystals, but also granular and columnar. The color is like that of potassium dichromate.

PHYSICAL CHARACTERS.—Translucent. Lustre, adamantine. Color, hyacinth red. Streak, orange yellow. H., 2.5 to 3. Sp. gr., 5.9 to 6.1. Sectile. Cleavage, prismatic.

BEFORE BLOWPIPE, ETC.—In closed tube, decrepitates violently, becomes dark, but recovers color on cooling. Fuses very easily, and is reduced to metallic lead with deflagration, the coal being coated with a yellow sublimate. With borax or S.Ph., forms yellow glasses, which are bright green when cold. Soluble in nitric acid to a yellow solution. Fused with $KHSO_4$ on platinum, yields a dark-violet mass, red on solidifying and greenish-white when cold which distinguishes it from vanadinite.

VANADINITE.

COMPOSITION.—$3Pb_3(VO_4)_2 \cdot PbCl_2$ or $Pb_5Cl(VO_4)_3$, (PbO, 78.7; V_2O_5, 19.4; Cl, 2.5 per cent.), often with P or As replacing V.

GENERAL DESCRIPTION.—Small, sharp, hexagonal prisms, sometimes hollow, of bright-red, yellow or brown color. Also parallel groups and globular masses of crystals.

CRYSTALLIZATION.—Hexagonal. Class third order pyramid, p. 37. Axis $\dot{c} = 0.712$. Simple prism m with base c, or more rarely with pyramid p and *third order* pyramid $v = \frac{3}{2}a : 3a : a : 3c$, Fig. 455.

FIG. 454.

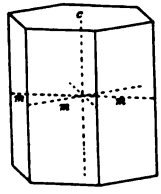
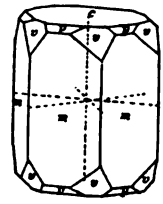


FIG. 455.



Physical Characters. H., 3. Sp. Gr., 6.66 to 7.23.

LUSTRE, resinous on fracture. OPAQUE, or translucent.

STREAK, white to pale yellow. TENACITY, brittle.

COLOR, deep red, bright red, yellow or brown.

BEFORE BLOWPIPE, ETC.—Fuses easily on charcoal to a blac mass, yielding a yellow sublimate in the reducing flame. Th residue gives deep-green bead, with salt of phosphorus in the re ducing flame. With strong nitric acid the substance becomes dee red, then dissolves to a yellow solution. Fused with KHSO yields a clear yellow, then a red, and finally yellow when cold.

USES.—It is the source of vanadium, for vanadium black; fo vanadium salts, which are used as a mordant in the manufactur of the finest silks; for vanadium bronze and for vanadium ink.

DESCLOIZITE.

COMPOSITION. — $(Pb.Zn)(PbOH),VO_4$, (PbO, 55.4; ZnO, 19.7; V_2O_5, 22.; H_2O, 2.2).

GENERAL DESCRIPTION.—Small purplish-red, brown or black crystals, formi a drusy surface or crust. Also fibrous, massive.

PHYSICAL CHARACTERS.—Transparent to nearly opaque. Lustre, greasy. Colo purplish red, brown or black. Streak, orange or brown. H., 3.5. Sp. gr., 5.9 to 6.

BEFORE BLOWPIPE, ETC.—On charcoal, fuses to black mass, enclosing meta In closed tube yields water. Vanadium reactions as in vanadinite.

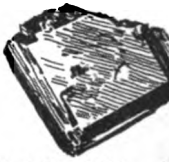
WULFENITE.

COMPOSITION.—$PbMoO_4$, sometimes containing Ca, Cr. V.

GENERAL DESCRIPTION.—Usually in thin, square, tabular cry tals of yellow, orange or bright orange-red color and resinou lustre. Less frequently in granular masses or acute pyramid crystals.

CRYSTALLIZATION.—Tetragonal. Class of hemimorphic pyramid p. Axis $c = 1.577$. Usually the base c with the pyramid $c = a : \infty\ a : \frac{1}{2}c$. More rarely the unit pyramid p and a third order prism $f = a : \frac{3}{2}a : \infty\ c$. Angle $ce = 141° 45'$, $pp = 99° 38'$. Optically —.

FIG. 456.



Red Cloud Mine, A zona.

FIG. 457.

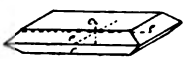


FIG. 458.

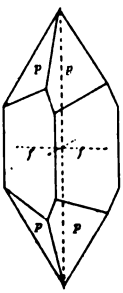


FIG. 459.

Physical Characters. H., 3. Sp. gr., 6.7 to 7.

LUSTRE, resinous or adamantine. TRANSLUCENT.

STREAK, white. TENACITY, brittle.

COLOR, wax yellow, bright red, brown, rarely green.

CLEAVAGE, pyramidal.

BEFORE BLOWPIPE, ETC.—Fuses easily on charcoal, giving yellow coat and finally a metallic globule. In salt of phosphorus dissolves to a bead, which is bright green in R. F. In borax, yields a colorless bead in O. F., which is made brown to black in R. F. Partially soluble in strong hydrochloric acid to a green liquid. If the solution is greatly diluted and stirred up with tin, it becomes deep blue and finally brown. A similar test may be obtained either by boiling in porcelain with strong sulphuric acid and adding alcohol, or by fusing in platinum with $KHSO_4$, dissolving in water and boiling with tin or zinc.

REMARKS.—Wulfenite occurs with other lead minerals, especially vanadinite and pyromorphite. It is found in many localities in New Mexico and Arizona; in the lead regions of Wisconsin and Missouri; at Phœnixville, Pa.; Inyo County, Cal.; Southampton, Mass., and many other places, always associated with other ores of lead.

STOLZITE.

COMPOSITION.—$PbWO_4$, (PbO, 49.0; WO_3, 51.0 per cent.).

GENERAL DESCRIPTION.—Very small, acute, tetragonal pyramids of gray or drab color.

PHYSICAL CHARACTERS.—Nearly opaque. Lustre, resinous. Color, gray, brown, green. Streak, white. H., 3. Sp. gr., 7.87 to 8.13.

BEFORE BLOWPIPE, ETC.—Fuses on charcoal to pearly crystalline globule. With soda, yields yellow coating and a metallic globule. Soluble in nitric acid, with separation of a yellow powder. In salt of phosphorus, with the reducing flame, gives a deep-blue to green glass, which powdered and boiled with dilute hydrochloric acid and tin, yields a deep-blue solution.

THE BISMUTH MINERALS.

The minerals described are: *Metal*, BISMUTH; *Sulphides*, BISMUTHINITE, AIKINITE; *Telluride*, TETRADYMITE; *Oxide*, BISMITE; *Carbonate*, BISMUTITE. Bismuth is also found intimately mixed with other minerals, as with tin ore in Bolivia; cobalt ore in Saxony and gold-bearing magnetite in Queensland, Australia.

The principal source of bismuth is the native metal; it is, however, extracted from the other minerals, and to a considerable extent from the hearths and last products of oxidation of lead cupella-

tion. The manufacture is practically all in Germany and Englan the latter country reducing Australian and Bolivian ores. Th quantity produced per year is small.

The uses of bismuth are chiefly dependent upon its property forming easily fusible alloys with other metals, especially tin, lea and cadmium. These alloys expand in cooling, and are therefo used in reproducing woodcuts, in making safety plugs for boile etc. The salts of bismuth have numerous uses in medicine and the arts, are used in calico printing, cosmetics, and in glass of hig refractive power, and to impart lustre to porcelain.

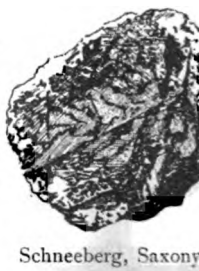
Bismuth was formerly obtained from the native metal by simp heating in a closed, inclined vessel, the liquid metal flowing ou This method was wasteful as any bismuth present as sulphide telluride was not obtained while much of the metal was lost. Saxony where most of the bismuth of the world is produced th ores are first roasted to free them from sulphur, arsenic and oth volatile constituents. After roasting they are smelted in crucibl with iron, charcoal and slag, the melted bismuth settling out the bottom of the crucible; or the roasted ores may be treat with strong hydrochloric acid (1 : 1) which dissolves the bismu and from which it is precipitated as oxychloride by the addition water. The metal may be further purified electrolytically. Wh in the cupellation of lead ore bismuth is found to be present, it recovered by saving the last products of oxidation and the hear of the furnace, grinding these and treating them with hot stro hydrochloric acid. After settling and cooling the liquid is siphon off and diluted with water, by which a precipitate of the oxychl ride is produced, which, after being dissolved in hydrochloric ac and reprecipitated some two or three times to separate lead chlorid is easily reduced to metallic bismuth by fusion with soda, or lim charcoal and a silicious slag.

BISMUTH.—Native Bismuth.

COMPOSITION—Bi, often alloyed with As or impure ftom S or Te.

GENERAL DESCRIPTION.—A brittle silver-white mineral with a reddish tinge, usually disseminated through the gangue in branching lines, Fig. 460, or in isolated grains or lumps. Rarely in indistinct hexagonal crystals.

FIG. 460.



Schneeberg, Saxony

Physical Characters. H., 2 to 2.5. Sp. gr., 9.7 to 9.83.
LUSTRE, metallic. OPAQUE.
STREAK, silver white. TENACITY, sectile to brittle.
COLOR, reddish silver white.

BEFORE BLOWPIPE, ETC.—On charcoal fuses easily and volatilizes completely, coating the charcoal with a yellow sublimate. With bismuth flux forms a chocolate brown and red coating which is best seen on plaster, and which is changed by action of ammonia fumes to red and orange. Soluble in strong nitric acid from which solution water will precipitate a white basic salt.

SIMILAR SPECIES.—Bismuth is characterized by its silver streak, reddish tinge, and arborescent structure.

REMARKS.—Bismuth occurs in crystalline rocks and clay slate associated with ores of cobalt, nickel, silver, gold, lead and zinc, also with molybdenite, wolframite, scheelite. The native metal is not found in any quantity in the United States, although obtained at Monroe, Ct., n Colorado, and in South Carolina. The most celebrated foreign localities are Schneeberg in Saxony and other places both in Saxony and Bohemia. Found also at Copiapo, Chili; in Bolivia, Sweden, Norway, and in South Australia.

USES.—It is a source of commercial bismuth and of salts of bismuth.

BISMUTHINITE.

COMPOSITION.—Bi_2S_3, (Bi 81.2, S 18.8 per cent.). May contain Cu or Fe.

GENERAL DESCRIPTION.—A lead gray mineral of metallic lustre usually occurring in foliated or fibrous masses, or in groups of long needle-like orthorhombic crystals.

PHYSICAL CHARACTERS.—Opaque. Lustre, metallic. Color, lead gray or lighter, often with yellow tarnish. Streak, lead gray. H., 2. Sp. gr., 6.4 to 6.5. Slightly sectile.

BEFORE BLOWPIPE, ETC.—On charcoal yields some sulphur, fuses easily with spirting, and coats the coal with white and yellow sublimates. Yields the characteristic bismuth reactions with bismuth flux and with nitric acid as described under bismuth. With soda gives sulphur reaction.

AIKINITE.—Needle Ore.

COMPOSITION.—$BiPbCuS_3$, (Bi 36.2, Pb 36, Cu 11, S 16.8 per cent.).

GENERAL DESCRIPTION.—Long embedded needle like crystals of dark gray color and metallic lustre. Also massive.

PHYSICAL CHARACTERS.—Opaque. Lustre, metallic. Color, blackish lead gray with copper red tarnish. Streak, lead gray. H., 2 to 2.5. Sp. gr., 6.1 to 6.8.

BEFORE BLOWPIPE, ETC.—Fuses on charcoal, yielding white and yellow sublimates. With bismuth flux on plaster yields chrome yellow coat of lead, chocolate and red coat of bismuth, and intense green flame of copper. The residues from treatment on coal yield in borax or salt of phosphorus greenish blue beads which in the reducing flame usually become black and opaque.

Soluble in nitric acid with separation of sulphur and lead sulphate.

TETRADYMITE.

COMPOSITION.—$Bi_2(Te.S)_3$ or BiTeS. Either an alloy or a telluride of bismuth.

GENERAL DESCRIPTION.—Very soft, flexible, foliated masses of steel-gray color a bright metallic lustre, or small indistinct rhombohedral crystals. Will mark paper l graphite.

PHYSICAL CHARACTERS, ETC.—Opaque. Lustre, metallic. Color, pale steel-gr Streak, gray. H., 1.5 to 2. Sp. gr., 7.2 to 7.6. Flexible in laminæ. Cleavage, ba

BEFORE BLOWPIPE, ETC.—On charcoal fuses easily and is completely volatiliz yielding a white fusible sublimate, followed by a yellow sublimate. The flame dur fusion is colored blue. The white sublimate if placed on porcelain and moiste with concentrated sulphuric acid becomes rose colored. If dropped into boiling c centrated sulphuric acid a deep violet color is produced.

BISMUTITE.

COMPOSITION.—$(BiO)_2CO_3.H_2O$, variable.

GENERAL DESCRIPTION.—A light colored incrustation or earthy mass or powder

PHYSICAL CHARACTERS.—Opaque. Lustre, dull or vitreous. Color, white, gr and yellow. Streak, colorless to greenish. H., 4–4.5, Sp. gr. 6.9–7.7. Tenac brittle.

BEFORE BLOWPIPE, ETC.—Fuses easily on charcoal, giving a yellow coat and R. F. a metallic globule which completely volatilizes. With bismuth flux on pla gives brown and red coat. Yields water in closed tube and decrepitates. Soluble v effervescence in strong HCl, and on dilution with much water the white oxychlorid bismuth is precipitated.

USES.—Is an important ore of bismuth.

REMARKS.—It is usually associated with metallic bismuth or the sulphide and occ at Brewer's Mine, S. C., Phoenix, Arizona, Inyo Co., Cal.

BISMITE.—Bismuth Ochre.

COMPOSITION.—Bi_2O_3, Bi.89.6 per cent. when pure.

GENERAL DESCRIPTION.—A yellowish or gray powder or earthy mass.

PHYSICAL CHARACTERS.—Opaque. Color, grayish, greenish or yellowish wh Lustre, dull.

BEFORE BLOWPIPE, ETC.—As for bismutite but does not effervesce with acids yield water in closed tube.

USES.—It is the source of some bismuth.

CHAPTER XXVI.

ARSENIC, ANTIMONY, URANIUM AND MOLYBDENUM MINERALS.

THE ARSENIC MINERALS.

The minerals described are: *Metal*, ARSENIC; *Sulphides*, ORPIMENT, REALGAR; *Oxide*, ARSENOLITE.

The principal sources of metallic arsenic and white arsenic are not the above mentioned minerals, but the arsenides and arsenosulphides of iron, cobalt and copper. The major part of the world's supply of arsenic and its compounds comes from Cornwall, England, Freiberg, Saxony, and from Prussia.

Metallic arsenic is ordinarily produced by sublimation from a mixture of the oxide and charcoal, but may be produced by sublimation at a high heat directly from arsenopyrite out of contact with air. It is a constituent of some useful alloys, shot metal being the chief.

The poisonous oxide commonly known as arsenic or white arsenic, is produced in large quantities by the roasting of arsenopyrite and other arsenical ores and as a by-product in the preparation of tin, silver, nickel and cobalt. It is used in dyeing, in medicine, in sheep washing, in calico printing, as a preservative for timber and for natural history specimens, in the manufacture of fly paper, and rat poisons, and in glass manufacture. Many important coloring matters as well as the artificial red and yellow sulphides are commercial products. Paris green is an arsenate of copper extensively used as an insecticide.

ARSENIC.—Native Arsenic.

COMPOSITION.—As, generally with some Sb and sometimes with Bi or a little Co, Ni, Fe, Ag or Au.

GENERAL DESCRIPTION.—A tin-white metal, tarnishing almost black. Usually granular, massive, with reniform surfaces. Can frequently be separated in concentric layers. Rarely found in needle-like crystals.

PHYSICAL CHARACTERS.—Opaque. Lustre, nearly metallic. Color, tin white, tarnishing nearly black. Streak, tin white. H., 3.5. Sp. gr., 5.63 to 5.73. Brittle. Granular fracture.

BEFORE BLOWPIPE, ETC.—On charcoal, volatilizes without fusion, yielding garlic odor, white fumes, crystalline white sublimate and pale blue flame. May a residue of impurities.

REALGAR.

COMPOSITION.—As_2S_2, (As, 70,1 ; S, 29.9 per cent.).

GENERAL DESCRIPTION.—A soft, orange-red mineral, of resi lustre, usually occurring in translucent, granular masses, but compact and in transparent monoclinic crystals.

Physical Characters. H., 1.5 to 2. Sp. gr., 3.4 to 3.6.

LUSTRE, resinous. TRANSLUCENT to transpare
STREAK, orange red. TENACITY, slightly sectile.
COLOR, aurora red, becoming orange yellow on long expos

BEFORE BLOWPIPE, ETC.—On charcoal, fuses easily, burns a blue flame, yields white fumes, with garlic odor and also of sulphur dioxide and is volatilized completely. In closed yields red sublimate. Soluble in nitric acid, with separatio sulphur. Soluble also in potassium hydroxide from which drochloric acid precipitates yellow flakes.

REMARKS.—Realgar is found with orpiment, arsenolite, galenite, argentite, et is formed both by sublimation and by deposition from water. Realgar is ob mainly from abroad, notably from Hungary and the island of Borneo. Depos known in Utah, California and Wyoming.

USES.—The artificial sublimate is used in fireworks and for nalling, in the form of "white Indian fire." It also is used pigment.

ORPIMENT.

COMPOSITION.—As_2S_3, (As, 61 ; S, 39 per cent.).

GENERAL DESCRIPTION.—Lemon-yellow, foliated masses, w cleave into thin, pearly, flexible scales, and also granular m like yolk of hard-boiled eggs. Less frequently as reniform c and imperfect orthorhombic crystals.

Physical Characters. H., 1.5 to 2. Sp. gr., 3.4 to 3.6.

LUSTRE, resinous or pearly. TRANSLUCENT to nearly opaq
STREAK, lemon yellow. TENACITY, slightly sectile.
COLOR, lemon yellow. CLEAVAGE, in plates or leaves

BEFORE BLOWPIPE, ETC.—As for realgar, except that the sublimate in closed tube is yellow.

REMARKS.—Probably generally formed by sublimation, but is also deposited from hot water, and formed by alteration of realgar in air and sunlight. It occurs with realgar, arsenic, arsenolite, etc. Obtained mainly from several Hungarian localities, from Borneo, and from Kurdistan, Turkey. Found in powder at Edenville, N. Y., and massive in Wyoming, Utah and Nevada.

USES.—The artificial material is used in dyeing to reduce indigo, and in tanning, as a constituent with potash and lime, to remove hair from skins.

ARSENOLITE.

COMPOSITION.—As_2O_3, (As, 75 8 per cent.).

GENERAL DESCRIPTION.—Minute white, hair-like crystals or yellowish or white crust upon arsenical ores. Very rarely as distinct octahedral crystals. Sweetish taste.

PHYSICAL CHARACTERS.—Transparent to opaque. Lustre, vitreous or silky. Color, white to yellowish. Streak, white. H., 1.5. Sp. gr., 3.7 to 3.72. Taste, sweetish astringent.

BEFORE BLOWPIPE, ETC.—On charcoal, volatilizes completely, forming white sublimate. With R. F., yields garlic odor. Slightly soluble in hot water. Poisonous.

THE ANTIMONY MINERALS.

The minerals described are: *Metal*, ANTIMONY; *Sulphides*, STIBNITE, KERMESITE; *Oxides*, VALENTINITE, SENARMONTITE. Lead ores also frequently contain antimony.

The only commercially important antimony mineral is the sulphide, which is used to a slight extent as sulphide in vulcanizing rubber, and in safety matches, percussion caps, fireworks, etc., but is chiefly important as a source of the metal. In 1899 this country produced 1000 tons * of metallic antimony, and used about four times that quantity, chiefly in preparing type and stereotype metal and other alloys. Type metal is now, however, principally produced from antimonial lead obtained as a by product in refining base bullion.

France, Italy, Mexico and Japan are at present the chief producers.

In smelting, the ore is heated and the melted sulphide drained off. The sulphide may then be roasted, forming the oxide, which is easily reduced by fusion with charcoal, or more frequently the sulphide is mixed with wrought-iron scraps and salt, placed in a crucible and fused. The iron combines with the sulphur and the metallic antimony settles to the bottom.

* *Engineering and Mining Journal*, 1900, p. 2.

The metal produced by either method is usually refine smelting with sodium carbonate and a little antimony sul followed by two fusions with sodium carbonate alone.

ANTIMONY.—Native Antimony.

COMPOSITION.—Sb, sometimes with As, Fe or Ag.

GENERAL DESCRIPTION.—A very brittle, tin-white metal, usually massive, wit granular, steel-like texture or lamellar or radiated. Very rarely in rhombo crystals or complex groups.

PHYSICAL CHARACTERS.—Opaque. Lustre, metallic. Color, tin white. S tin white. H., 3 to 3.5. Sp. gr., 6.5 to 6.72. Very brittle.

BEFORE BLOWPIPE, ETC.—Fuses very easily, colors the flame pale green, copious white fumes, which continue to form as a thick cloud after cessation of and often yield a crust of needle-like crystals.

STIBNITE.—Gray Antimony.

COMPOSITION.—Sb_2S_3, (Sb 71.8, S 28.2 per cent.). Somet contains silver or gold.

GENERAL DESCRIPTION.—A lead-gray mineral of bright me lustre, occurring in imperfectly crystallized masses, with colu or bladed structure; less frequently in distinct, prismatic, o rhombic crystals or confusedly interlaced bunches of needle crystals; also in granular to compact masses.

FIG. 461.

Iyo, Japan.

FIG. 462.

Felsobanya, Hungary.

CRYSTALLIZATION.—Orthorhombic. Axes $\breve{a} : \bar{b} : \dot{c} = 0.993$ 1.018. Prismatic forms, often bent and curved or in diver groups. The vertical planes are striated longitudinally.

Common forms: unit prism m, unit pyramid p and pyra $s = \breve{a} : \bar{b} : \frac{1}{3}\,c$. Angles $mm = 90°\ 26'$; $pp = 109°\ 12'$; 144° 24′.

Physical Characters. H., 2. Sp. gr, 4.52 to 4.62.

LUSTRE, metallic. OPAQUE.

STREAK, lead gray. TENACITY, brittle to sectile.

COLOR, lead gray, often with black or iridescent tarnish.

CLEAVAGE, easy, parallel to brachy pinacoid, yielding slightly flexible, blade-like strips.

BEFORE BLOWPIPE, ETC.—On charcoal, fuses very easily, yielding the same dense sublimate as antimony. The odor of sulphur dioxide may also be noticed. On charcoal, with soda, yields sulphur test. In closed tube fuses easily, yields a little sulphur and a dark sublimate which is brownish red when cold.

Soluble completely in strong boiling hydrochloric acid, with evolution of H_2S, with precipitation of white basic salt on addition of water and after dilution an orange precipitate on addition of H_2S. Strong nitric acid decomposes stibnite into white Sb_2O_5 and S. Strong hot solution of KOH colors stibnite yellow and partially dissolves it. From the solution hydrochloric acid will throw down an orange precipitate.

SIMILAR SPECIES.—Differs from galenite in cleavage, and from all sulphides by ease of fusion and cloud-like fumes.

REMARKS.—Stibnite occurs in veins with other antimony minerals formed from it, also with cinnabar, sphalerite, siderite, etc. Large deposits of stibnite occur at Lovelocks, Bernier and Austin, Nevada; at Kingston, Idaho; at San Emidio, California; in Arkansas, in Utah, in Nova Scotia and in New South Wales. The most celebrated deposit, however, is that in Shikoku, Japan, from which the very finest crystals and groups are obtained.

USES.—It is the chief source of antimony and its artificial pigment and pharmaceutical preparations. In the natural state it is used in safety matches and percussion caps, in fireworks, in rubber goods and in refining gold.

KERMESITE.—Red Antimony.

COMPOSITION.—Sb_2S_2O or $2Sb_2S_3{\cdot}Sb_2O_3$, (Sb 75.0, S 20.0, O 5.0 per cent.).

GENERAL DESCRIPTION.—Fine hair-like tufts of radiating fibres and needle-like crystals, of a deep cherry-red color and almost metallic lustre.

PHYSICAL CHARACTERS.—Nearly opaque. Lustre, adamantine. Color, dark cherry red. Streak, brownish red. H., 1 to 1.5. Sp. gr., 4.5 to 4.6. Sectile and in thin leaves slightly flexible.

BEFORE BLOWPIPE, ETC.—As for stibnite.

REMARKS.—Kermesite results from partial oxidation of stibnite. Extensive deposits exist at Pereta, Tuscany.

SENARMONTITE.

COMPOSITION.—Sb_2O_3, (Sb, 83.3 per cent.).

GENERAL DESCRIPTION.—Colorless to gray octahedral crystals and granular mass

PHYSICAL CHARACTERS.—Transparent to translucent. Lustre, resinous. Col colorless or gray. Streak, white. H., 2 to 2.5. Sp. gr., 5.22 to 5.30.

BEFORE BLOWPIPE, ETC.—Fuses easily, coating the charcoal with white oxide. R. F. is reduced, but again oxidizes and coats the coal, coloring the flame green. So ble in hydrochloric acid.

REMARKS.—Formed by oxidation and decomposition of stibnite and other ores antimony.

VALENTINITE.

COMPOSITION.—Sb_2O_3, (Sb, 83.3 per cent.).

GENERAL DESCRIPTION.—Small white flat crystals (orthorhombic) or fan-shap groups of a somewhat silky lustre and white or gray color. Also in spheroidal mas with radiated lamellar structure.

PHYSICAL CHARACTERS.—Translucent. Lustre, adamantine or silky. Color, wh gray, pale red. Streak, white. H., 2.5 to 3. Sp. gr., 5.57.

BEFORE BLOWPIPE, ETC.—As for senarmontite.

THE URANIUM MINERALS.

The minerals described are: *Uranate*, URANINITE; *Phosphat* AUTUNITE, TORBERNITE.

The metal uranium has a limited use in uranium steel, as a sm percentage of uranium increases the elasticity and hardness of dinary steel.

A few tons of sodium uranate, commercially known as urani yellow are used yearly in coloring glass yellow with a green reflex, and in coloring porcelain orange or black. A small amou is used in photography.

URANINITE.—Pitch Blende.

COMPOSITION.—A uranate of UO_2, Pb, etc., and may contain N, Th, Zr, Fe, Cu, Bi, etc.

GENERAL DESCRIPTION.—A black massive mineral of botryoi or granular structure and pitch-like appearance. Rarely in sm isometric crystals.

Physical Characters. H., 5.5. Sp. gr., 5 to 9.7.

LUSTRE, pitch-like, submetallic. OPAQUE.

STREAK, gray, olive green, dark brown. TENACITY, brittle.

COLOR, some shade of black.

BEFORE BLOWPIPE, ETC.—Infusible or very slightly fused

edges, sometimes coloring the flame green from copper. On charcoal with soda may yield reaction for lead, arsenic and sulphur. In borax yields a green bead made enamel black by flaming. Soluble in nitric acid to a yellow liquid from which ammonia throws down a bright yellow precipitate.

SIMILAR SPECIES.—The appearance and streak are frequently sufficient distinctions. The bead tests are characteristic.

REMARKS.—Uraninite occurs both in granitic rocks and in metallic veins. It is frequently associated with minerals resulting from its decomposition and with metallic ores. It is mined at Joachimstal, Bohemia, from whence the principal supply is obtained. It occurs in Jefferson and Gilpin counties, Colorado, having been mined at Central City and is found also in some quantity in Mitchell county, N. C., at Marietta, S. C., in Texas, and in the Black Hills of South Dakota.

USES.—Uraninite is the chief source of the uranium salts used in painting on porcelain and in the manufacture of a fluorescent glass of yellowish-green color.

AUTUNITE—Lime Uranite.

COMPOSITION.—$Ca(UO_2)_2(PO_4)_2 + 8H_2O$, ($UO_3$ 62.7, CaO 6.1, P_2O_5 15.5, H_2O 15.7 per cent.).

GENERAL DESCRIPTION.—Little square ($I \wedge I$ 90° 43′) orthorhombic plates of bright yellow color and pearly lustre, or in micaceous aggregates.

PHYSICAL CHARACTERS.—Translucent. Lustre, pearly on base. Color, lemon to sulphur yellow. Streak, pale yellow. H., 2 to 2.5. Sp. gr., 3.05 to 3.19. Brittle. Cleavage basal.

BEFORE BLOWPIPE, ETC.—On charcoal fuses with intumescence to a black crystalline globule. With salt of phosphorus or borax in the reducing flame yields a green bead. Dissolves in nitric acid to a yellow solution.

TORBERNITE.—Copper Uranite.

COMPOSITION.—$Cu(UO_2)_2(PO_4)_2 + 8H_2O$, ($UO_3$ 61.2, CuO 8.4, P_2O_5 15.1, H_2O 15.3 per cent.).

GENERAL DESCRIPTION.—Thin square tetragonal plates of bright green color and pearly lustre. Sometimes in pyramids or micaceous aggregates.

PHYSICAL CHARACTERS.—Translucent. Lustre, pearly. Color, emerald to grass green. Streak, pale green. H., 2 to 2.5. Sp. gr., 3.4 to 3.6. Brittle.

BEFORE BLOWPIPE, ETC.—Fuses easily to a black mass and colors the flame green. In borax yields a green glass in O. F., which becomes opaque red in R. F. Soluble in nitric acid to a yellowish green solution.

THE MOLYBDENUM MINERALS.

The minerals described are: *Sulphide*, MOLYBDENITE; *Oxide*, MOLYBDITE. Besides these molybdenum occurs as the acid constituent of Wulfenite elsewhere described.

The metal has a limited use in the production of an alloy w steel. Its chief important compounds are sodium molybdate us to impart a blue color to pottery and in dyeing silks and woole and molybdic acid from which useful chemical reagents are p pared in the laboratory.

MOLYBDENITE.

COMPOSITION.—MoS_2, (Mo 60.0, S 40.0 per cent.).

GENERAL DESCRIPTION.—Thin graphite-like scales or foliat masses of metallic lustre and bluish gray color, easily separat into flexible non-elastic scales. Sometimes in tabular hexagon forms and fine granular masses. Soft, unctuous and marks pap

Physical Characters. H., 1 to 1.5. Sp. gr., 4.6 to 4.9.

LUSTRE, metallic.	OPAQUE.
STREAK, greenish.*	TENACITY, sectile to malleab
COLOR, bluish lead gray.	CLEAVAGE, basal.

BEFORE BLOWPIPE, ETC.—In forceps infusible, but at high he colors the flame yellowish green. On charcoal gives sulphuro odor and slight sublimate, yellow hot, white cold, and deep bl when flashed with the reducing flame. Soluble in strong nitr acid and during solution on platinum it is luminous. With su phuric acid yields a blue solution. In salt of phosphorus an borax yields characteristic molybdenum reactions.

SIMILAR SPECIES.—Differs from graphite in streak and blowpi reactions. May usually be distinguished by its lighter bluish gra color.

REMARKS.—Occurs usually in crystalline rocks, and is not readily altered. It is fou in many American localities, but is not mined. Westmoreland, N. H., Blue Hill Ba Maine, and Pitkin, Colorado, have probably the largest American deposits.

USES.—It is the source of the molybdenum salts which are im portant chiefly in analytical work.

MOLYBDITE.

COMPOSITION.—MoO_3, (Mo 66.7 per cent.).

GENERAL DESCRIPTION.—An earthy yellow powder or, rarely, tufts and hair-li crystals of yellowish-white color.

PHYSICAL CHARACTERS.—Opaque to translucent. Lustre, dull or silky. Colo yellow or yellowish white. Streak, straw yellow. H., 1 to 2. Sp. gr., 4.49 to 4.5.

BEFORE BLOWPIPE, ETC.—On charcoal fuses, yielding crystals yellow hot, whi cold, and made deep blue by the reducing flame. In borax and salt of phosphor gives characteristic molybdenum reactions.

* Best seen on glazed porcelain.

CHAPTER XXVII.

THE COPPER MINERALS.

The minerals described are: *Metal*, COPPER; *Sulphides*, CHALCOCITE, BORNITE, CHALCOPYRITE; *Sulphoarsenides*, ENARGITE, TENNANTITE; *Sulphoantimonides*, TETRAHEDRITE; *Oxides*, CUPRITE, TENORITE; *Oxychloride*, ATACAMITE; *Sulphates*, CHALCANTHITE, BROCHANTITE; *Phosphate*, LIBETHENITE; *Arsenate*, OLIVENITE; *Carbonates*, MALACHITE, AZURITE; *Silicates*, CHRYSOCOLLA, DIOPTASE. In addition to these the iron sulphides often carry copper which is extracted after burning for sulphuric acid.

The chief copper minerals are chalcopyrite and bornite, native copper, cuprite, malachite and azurite, though with the exception of two or three, all the others above mentioned are sufficiently plentiful to be considered as ores. The world's product* of copper in 1898 was 434,329 long tons of which this country produced 239,241 tons. In 1899 the output of the United States had increased to 264,586 tons†, and of the total product of the world, about one-fourth was derived from the sulphide ores of Montana, and one-sixth from the native copper of Michigan. Altogether, the United States yields about two-thirds of the copper annually produced.

The method of extraction of the copper is dependent upon the nature of the ore, and may roughly be classed under three headings:

Treatment of native copper.

Treatment of oxidized ores.

Treatment of sulphides.

A great many processes exist or have existed, but these for a general brief discussion may be reduced to a small number of type processes of which the others are variations due to local conditions or constituents of the ore.

Treatment of Native Copper.

Native copper occurs in enormous quantities in Michigan, and the deposits mined average less than two per cent. of copper, although occasionally large masses of the metal are found. The rock is crushed by steam stamps and the copper separated from

* *Mineral Industries*, 1899, pp. 213 *et seq.*

† *Engineering and Mining Journal*, 1900, p. 2.

the rock by the action of water and the use of jigs, tables, and c
concentrating apparatus. The concentrated material is then m
in a large reverberatory furnace with limestone and slags from p
ous operations. The new slag thus formed contains the ren
ing rock and is removed, leaving behind copper, which af
period of reduction by charcoal and stirring is cast into ingot

Treatment of Oxidized Ores.

The oxidized ores in Arizona which average over ten per
of copper, are smelted in blast-furnaces with coke and the ne
sary flux to make a slag with the associated gangue. The r
is an impure metal called black copper, which is later refined.

Treatment of Sulphides.

The treatment of sulphides is quite varied, depending chiefl
the presence or absence of arsenic, the richness of the ore and
local conditions. The ores always contain iron, copper and
phur, and may contain arsenic, antimony, silver, gold, etc.
the smelting processes depend on the facts that at high temp
tures copper has a greater affinity for sulphur than iron has,
iron a stronger affinity than copper for oxygen. So that if
an ore is subjected to oxidation by roasting, oxides result; bu
the subsequent fusion, if enough sulphur has been left, the co
will form a fusible sulphide, and the oxidized iron will unite
the gangue and the flux to form a slag.

By regulating the roasting, the sulphur contents may be brou
to any desired percentage. This may be just sufficient to sa
the copper or to satisfy also a great deal of the iron producin
low-grade sulphide (matte), which, by re-roasting and refusio
enriched. The low-grade matte means a smaller loss of co
in the slags, and is often of service in assisting the removal of
senic and antimony.

When the matte has reached the required percentage of cop
it is roasted as free from sulphur as possible, and being now es
tially an oxide, it may be smelted for copper either in a shaft-
nace, much as the oxidized ores are, or, when silver or gol
present, in a reverberatory furnace.

In a more recent method the ores are roasted and fused,
ducing a matte containing over fifty per cent. of copper.
matte, while liquid, is run into a sort of Bessemer converter,

a blast turned on, by which the sulphur, arsenic and antimony are driven off, the iron oxidized and converted into slag, and black copper obtained.

The crude copper is refined either by remelting and oxidation, or more frequently electrolytically.

The great uses of copper are in electrical work and in alloys with zinc and tin, such as brass, yellow metal, bronze, bell metal, German silver, etc. In 1899 about 30,000 tons of copper sulphate were made in the United States.

COPPER.

COMPOSITION.—Cu often containing Ag, sometimes Hg or Bi.

GENERAL DESCRIPTION. — A soft, *red*, malleable metal, with a red streak. Usually in sheets or disseminated masses, varying from small grains to several hundred tons in weight. Also in threads and wire and in distorted crystals and twisted groups.

FIG. 463.

Lake Superior.

CRYSTALLIZATION.—Isometric. Tetrahexahedron and cube most frequent, also twinned, Fig. 466, giving by elongation spear-shaped forms often complexly grouped and usually distorted. See Fig. 312.

FIG. 464.

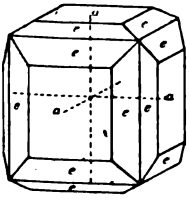
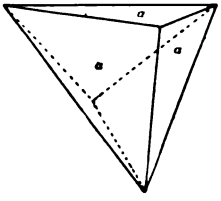


FIG. 465.

Lake Superior.

FIG. 466.



Physical Characters. H., 2.5 to 3. Sp. gr., 8.8 to 8.9.

LUSTRE, metallic. OPAQUE.

STREAK, copper red. TENACITY, malleable and ductile.

COLOR, copper red, tarnishing nearly black.

BEFORE BLOWPIPE, ETC.—Fuses easily to a malleable globule, often coated with a black oxide. In beads, becomes in O. F. green when hot; blue, cold, and in R. F. opaque red. Soluble in nitric

acid, with evolution of a brown gas, to a green solution, which w deposit copper on iron or steel. The solution becomes deep azu blue on addition of ammonia.

SIMILAR SPECIES.—Resembles niccolite and tarnished silve differs in copper-red streak.

REMARKS.—Occurs with native silver and ores of copper, and by oxidation m form cuprite or melaconite or the carbonates. In Michigan it occurs in trap conglomerate. It is especially apt to occur near dikes of igneous rocks. T great locality of the world for native copper, and the only locality still yielding t mineral in large quantities, is the Lake Superior region of Northern Michigan, a although the territory here covered is many square miles in extent, the Calumet a Hecla mine yields the major part of all that is produced. Although native copper also found in Arizona, California, and, to a limited extent, in other American loca ties, it is never mined for itself alone, nor does it constitute a large part of the copp ore present. The Coro-Coro mines, in Bolivia, are now producing some copper fr the native metal.

USES.—It is an important source of the copper of commerce.

CHALCOCITE.—Copper Glance.

COMPOSITION.—Cu_2S, (Cu 79.8, S 20.2 per cent.).

GENERAL DESCRIPTION.—Black granular or compact masse with metallic lustre or sometimes nodules or pseudomorphic aft wood. Often coated with the green carbonate, malachite. Als in crystals.

CRYSTALLIZATION.—Orthorhombic, $\breve{a} : \dot{b} : \dot{c} = 0.582 : 1 : 0.97$ $I \wedge I = 119° 35'$. $O \wedge 1 = 117° 24\frac{1}{2}'$. Tabular forms, pseud hexagonal or frequently twinned, making star-like groups.

Physical Characters. H., 2.5 to 3. Sp. gr., 5.5 to 5.8.

LUSTRE, metallic. OPAQUE.

STREAK, lead gray. TENACITY, brittle.

COLOR, blackish lead gray, with dull-black tarnish.

BEFORE BLOWPIPE, ETC.—On charcoal, fuses to a globule, yiel ing sulphur dioxide. With soda, yields a copper button and strong sulphur reaction. Colors flame emerald green, or if mois ened with hydrochloric acid, it colors the flame azure blue. borax or salt of phosphorus, yields copper beads. Soluble in nitr acid, leaving a residue of sulphur.

SIMILAR SPECIES.—It is more brittle than argentite, and diffe from bornite in not becoming magnetic on fusion.

REMARKS.—Chalcocite occurs with other copper minerals and with hematit

galenite and cassiterite. Is found at Butte, Montana, and other American localities of less importance. Fine crystals are obtained from Cornwall, England.

USES.—It is an ore of copper.

BORNITE.—Purple Copper Ore. Horse Flesh Ore.

COMPOSITION.—Cu_3FeS_3, (Cu 55.5, Fe 16.4, S 28.1 per cent.), but often contains admixed chalcocite.

GENERAL DESCRIPTION.—On fresh fracture, bornite is of a peculiar red-brown color and metallic lustre. It tarnishes to deep blue and purple tints, often variegated. Usually massive, sometimes small cubes or other isometric forms.

Physical Characters. H., 3. Sp. gr., 4.9 to 5.4.

LUSTRE, metallic. OPAQUE.

STREAK, grayish black. TENACITY, brittle.

COLOR, dark copper red, brownish or violet blue, often varied.

BEFORE BLOWPIPE, ETC.—Blackens, becomes red on cooling, and finally fuses to a brittle, magnetic globule and evolves sulphur dioxide fumes. In oxidizing flame with borax or salt of phosphorus, gives green bead when hot, greenish blue when cold, the bead is opaque red in the reducing flame. Soluble in nitric acid, with separation of sulphur.

REMARKS.—On account of its high percentage of copper, it is especially valuable as an ore of copper when found in quantity. A large portion of the ore of many of the Chilian mines consists of bornite, and it has been found in quantity in the Montana copper regions. Also found at Bristol, Conn.; Acton, Canada: in Mexico, in Peru and other copper regions.

USES.—It is an important ore of copper.

CHALCOPYRITE.—Copper Pyrites. Yellow Copper Ore.

COMPOSITION.—$CuFeS_2$, (Cu 34.5, Fe 30.5, S 35.0 per cent.), with mechanically intermixed pyrite at times.

GENERAL DESCRIPTION.—A bright brassy yellow mineral of metallic lustre, often with iridescent tarnish resembling that of bornite. Usually massive. Sometimes in crystals.

CRYSTALLIZATION.—Tetragonal. Scalenohedral class p. 31. Axis $\dot{c} = 0.985$.

Sphenoids predominate p = unit sphenoid; $o = a : a : \frac{1}{2}c$; $t = a : a : \frac{1}{4}c$; $v = a : a : 4c$; $s = a : 2a : c$

Angles (over top) $pp = 71° 20'$; $oo = 51° 8'$; $tt = 141° 35'$; $vv = 20° 21'$.

FIG. 467.

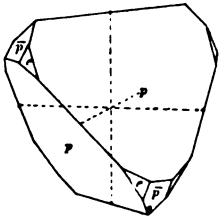
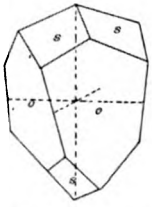
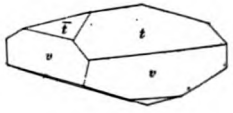


FIG. 468.



French Creek, Pa.

FIG. 469.



Ellenville, N. Y.

Physical Characters. H., 3.5 to 4. Sp. gr., 4.1 to 4.3.

LUSTRE, metallic. OPAQUE.

STREAK, greenish black. TENACITY, brittle.

COLOR, bright brass yellow, often tarnished in blue, purple an black hues.

BEFORE BLOWPIPE, ETC.—On charcoal fuses with scintillation t a brittle magnetic globule. With soda yields metallic malleabl red button and sulphur test. In closed tube decrepitates, become dark and iridescent and may give deposit of sulphur. Flame an bead reaction like bornite. Soluble in nitric acid with separatio of sulphur, and from the solution ammonia throws down a brow precipitate, and leaves the liquid deep blue in color.

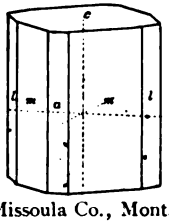
SIMILAR SPECIES.—Chalcopyrite is softer and darker in colo than pyrite, and differs from gold in black streak and brittleness.

REMARKS.—Chalcopyrite is probably formed in a manner similar to the formatio of pyrite which is its frequent associate. Its most prominent associated minerals a the metallic sulphides and copper ores, many of which have been formed by alteration. It sometimes contains gold or silver. It is a very widely distributed miner and the major part of all the copper produced is made from it. Prominent mines a in the Butte, Montana, region; and in Bingham Canyon, Utah. Also produced large quantities, at Falun in Sweden; Rio Tinto, Spain; Sudbury, Canada; and man other important localities.

USES.—It is the great ore of copper.

ENARGITE.

FIG. 470.



Missoula Co., Mont.

COMPOSITION.—Cu_3AsS_4, (Cu 48.3, As 19.1 S 32.6 per cent). Sometimes with Cu replace in part by Zn or Fe and As by Sb.

GENERAL DESCRIPTION.—A black brittle min eral of metallic lustre, and occurring usuall columnar or granular but sometimes in ortho rhombic crystals.

CRYSTALLIZATION.—Orthorhombic. Axes $\breve{a} : \bar{b} : \dot{c} = 0.871 : 1 : 0.825$. m = unit prism, $l = 2\breve{a} : \bar{b} : \infty c$. Angles are $mm = 97° 53'$; $ll = 59° 53'$.

Physical Characters. H., 3. Sp. gr., 4.43 to 4.45.

LUSTRE, metallic. OPAQUE.

STREAK, blackish gray. TENACITY, brittle.

COLOR, black or blackish gray.

BEFORE BLOWPIPE, ETC.—On charcoal fuses, yields white fumes with garlic odor. With soda yields malleable copper and a reaction for sulphur. In closed tube decrepitates, yields sulphur sublimate, then fuses and yields red sublimate of arsenic sulphide. Soluble in nitric acid.

REMARKS.—Enargite occurs with other copper minerals, especially arsenates derived from its alteration. It is found mainly in the mountains of Chili and Peru. Also at Butte, Montana, Gilpin county, Colorado; in South Carolina, Utah and California.

USES.—It is an ore of copper, and has been extensively mined.

TENNANTITE.

COMPOSITION.—$Cu_8As_2S_7$, grading into tetrahedrite by replacement of As by Sb.

GENERAL DESCRIPTION.—A black metallic mineral best known in isometric crystals but occurring massive in the Utah mines.

PHYSICAL CHARACTERS.—Opaque. Lustre, metallic. Color, black or very dark gray. Streak, dark reddish gray. H., 3.5 to 4. Sp. gr., 4.37 to 4.53.

BEFORE BLOWPIPE, ETC.—On coal fuses easily with intumescence and evolves white fumes with garlic odor. Frequently fuses to a magnetic globule due to the presence of iron. In closed tube decrepitates slightly. With soda yields malleable red button and sulphur reaction. Soluble in nitric acid.

TETRAHEDRITE.—Gray Copper Ore.

COMPOSITION.—$Cu_8Sb_2S_7$. Cu often partially replaced by Fe, Zn, Pb, Hg, Ag, and the Sb by As.

GENERAL DESCRIPTION.—A fine grained, dark gray mineral of metallic lustre. Characterized especially by the tetrahedral habit of its crystals which are sometimes coated with yellow chalcopyrite.

FIG. 471.

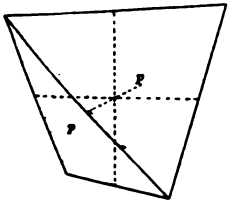


FIG. 472.

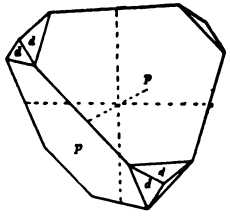


FIG. 473.

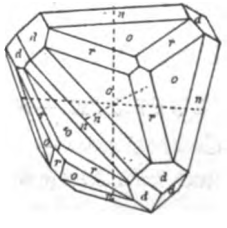


FIG. 474.

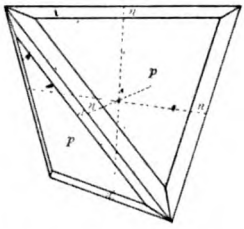


FIG. 475.

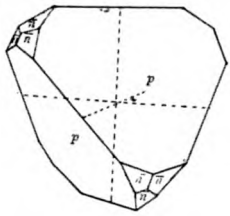
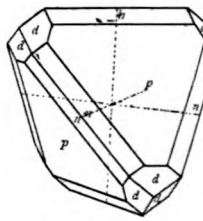


FIG. 476.



CRYSTALLIZATION.—Isometric. Hextetrahedral class p. The tetrahedron *p*, Fig. 471, usually predominates, often modif by the tristetrahedron $n = a : 2a : 2a$, Figs. 474, 475, 476 and l frequently by other forms such as the dodecahedron *d*, Figs. 4 476, and the tristetrahedron $r = a : a : 2a$, Fig. 473.

Physical Characters. H., 3 to 4.5. Sp. gr., 4.5 to 5.1.

LUSTRE, metallic. OPAQUE.

STREAK, black or reddish brown. TENACITY, brittle.

COLOR, light steel to dark lead gray or iron black.

BEFORE BLOWPIPE, ETC.—On charcoal fuses easily to a globu which may be slightly magnetic. Evolves heavy white fum with sometimes garlic odor. The roasted residue gives bead a flame reactions for copper. Soluble in nitric acid to a green sol tion with white residue.

VARIETIES—Varieties based upon the replacing metal as mercur argentiferous, platiniferous, bismuthiferous, etc., are given spec names as *Freibergite*, *Schwatzite*, *Rionite*, etc.

SIMILAR SPECIES.—The crystals are characteristic. The fi grained fracture in conjunction with the color is often sufficient distinguish it. It is softer than arsenopyrite and the metallic cob ores, and does not generally yield a strongly magnetic residue heating. Bournonite and chalcocite are softer, and finally t blowpipe reactions are distinctive.

REMARKS.—Occurs with the sulphides of lead, silver, copper, etc., especially Humbolt County, Nevada, and numerous localities in Colorado. Also in Mexi Bolivia, Chili, and in many parts of Europe.

USES.—It is sometimes worked for silver and also for copper.

CUPRITE.—Red Oxide of Copper, Ruby Copper Ore.

COMPOSITION.—Cu_2O, (Cu 88.8 per cent.). Sometimes inte mixed with limonite.

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GENERAL DESCRIPTION.—Fine grained, masses dark red, brownish-red and earthy brick-red in color; or deep red to crimson transparent isometric crystals usually octahedrons, or cubes. Also capillary.

FIG. 477.

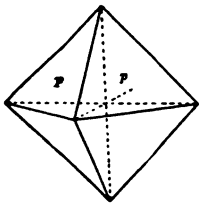


FIG. 478.

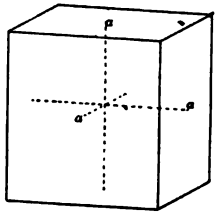
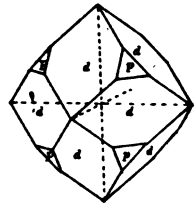


FIG. 479.



CRYSTALLIZATION.—Isometric. Class of gyroid. The octahedron *p*, cube *a* and dodecahedron *d* predominating. Index of refraction for red light 2.849.

Physical Characters. H., 3.5 to 4. Sp. gr., 5.85 to 6.15.
LUSTRE, adamantine or dull. TRANSPARENT to opaque.
STREAK, brownish red. TENACITY, brittle.
COLOR, crimson, scarlet, vermilion, or brownish red.

BEFORE BLOWPIPE, ETC.—On charcoal blackens and fuses easily to a malleable red button. Flame and bead tests give the color for copper. Soluble in nitric acid to a green solution. Soluble also in strong hydrochloric acid to a brown solution which diluted with water yields a white precipitate.

SIMILAR SPECIES.—It is softer than hematite and harder than cinnabar or proustite, and differs from them all by yielding an emerald-green flame and a malleable red metal on heating.

REMARKS.—It is formed by oxidation of sulphides or the metal, and is found near the surface associated with limonite, quartz, and copper minerals. It changes to the black oxide and to the carbonates and silicate. In the United States it is especially abundant in the Arizona copper region. Also found in the Lake Superior region, and is abundant in Chili, Peru and Bolivia in association with the other copper ores.

USES.—It is an important ore of copper.

TENORITE.—Melaconite, Black Oxide of Copper.

COMPOSITION.—CuO, (Cu 79.85 per cent.).

GENERAL DESCRIPTION.—Dull black earthy masses, black powder and shining black scales.

PHYSICAL CHARACTERS.—Lustre, metallic in scales, dull in masses. Color and streak black. H., 3. Sp. gr., 5.82 to 6.25.

BEFORE BLOWPIPE, ETC.—Infusible, otherwise like cuprite.

REMARKS.—Occurs in fissures in the lava of Vesuvius, as a black coat on chal
rite and as dull black masses with chrysocolla.

ATACAMITE.

COMPOSITION.—$Cu(OH)Cl{\cdot}Cu(OH)_2$, (Cu 59.45, Cl 16.64 per cent.).

GENERAL DESCRIPTION.—Confused aggregates of crystals of bright or dark-
color. Also granular or compact massive, or as a crust. Rarely in slender orthor
bic prisms.

PHYSICAL CHARACTERS.—Translucent to transparent. Lustre, adamantine t
reous. Color, bright green, emerald green, blackish green. Streak, apple g
H., 3 to 3.5. Sp. gr., 3.75 to 3.77.

BEFORE BLOWPIPE, ETC.—On charcoal, fuses to a copper red, malleable button
colors the flame a beautiful and persistent blue *without the aid of hydrochloric acid*
closed tube yields water and a gray sublimate. Soluble in acids to a green solut

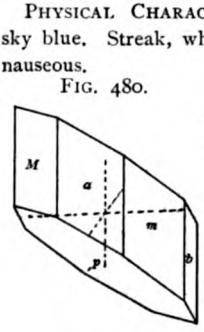
CHALCANTHITE.—Blue Vitriol.

COMPOSITION.—$CuSO_4{\cdot}5H_2O$, (CuO 31.8, SO_3 32.1, H_2O 36.1 per cent.).

GENERAL DESCRIPTION.—A blue, glassy mineral, with a disagreeable metallic t
It occurs usually as an incrustation, with fibrous, stalactitic or botryoidal structure
sometimes in flat triclinic crystals.

PHYSICAL CHARACTERS.—Translucent. Lustre, vitreous. Color, deep blu
sky blue. Streak, white. H., 2.5. Sp. gr., 2.12 to 2.30. Brittle. Taste, met
nauseous.

FIG. 480.



CRYSTALLIZATION.—Triclinic. Axes $\breve{a} : \breve{b} : \breve{c} = 0.566$
0.551. Axial angles $a = 82° 21'$; $\beta = 73° 11'$; $\gamma = 77°$
Prominent forms, right and left unit prism *m* and *M*, unit
mid *p*, and the pinacoids *a* and *b*. Angles $mM = 123°$
Optically—.

BEFORE BLOWPIPE, ETC.—On charcoal, fuses, coloring
green and leaving metallic copper. In closed tube yields
and sulphur dioxide and leaves a white powder. Easily so
in water to a blue solution.

REMARKS.—It is produced by oxidation of the sulphide
pecially chalcopyrite. Copper is sometimes saved by precipitation from mine w
containing chalcanthite.

BROCHANTITE.

COMPOSITION.—$CuSO_4\ 3\ Cu(OH)_2$, (CuO 70.34, SO_3 17.71 H_2O 11.95 per c

GENERAL DESCRIPTION.—Velvety, emerald-green crusts of fine needle crystals
as botryoidal masses.

PHYSICAL CHARACTERS.—Transparent to translucent. Lustre, vitreous. C
emerald or blackish green. Streak, pale green. H., 3.5 to 4. Sp. gr., 3.9.

BEFORE BLOWPIPE, ETC.—On charcoal turns black, colors the flame emerald g
and leaves malleable red button. Insoluble in water, but soluble in acids. In cl
tube yields water.

LIBETHENITE.

COMPOSITION.—$Cu_2(OH)PO_4$, (CuO 66.4, P_2O_5 29.8, H_2O 3.8 per cent.).

GENERAL DESCRIPTION.—A dark, olive-green mineral, usually in druses of
prismatic orthorhombic crystals and more rarely compact.

PHYSICAL CHARACTERS.—Translucent. Lustre, resinous. Color, olive green. Streak, olive green. H., 4. Sp. gr., 3.6 to 3.8. Brittle.

BEFORE BLOWPIPE, ETC.—Fuses easily to a brown or reddish globule, coloring the flame emerald green, and yields metallic copper. Fused with lead yields a crystalline bead and metallic copper. In closed tube yields water and turns black. Soluble in nitric acid.

OLIVENITE.

COMPOSITION.—$Cu_2(OH)AsO_4$ (CuO 56.1, As_2O_5 40.7, H_2O 3.2 per cent.).

GENERAL DESCRIPTION.—Needle-like orthorhombic crystals of dark olive-green, also nodules and fibrous or velvety masses of light-green to gray or brown color.

PHYSICAL CHARACTERS.—Translucent to opaque. Lustre, adamantine to vitreous. Color, olive to blackish green, also yellow, brown, grayish white. Streak, olive green or brown. H., 3. Sp. gr., 4.1 to 4.4. Brittle.

BEFORE BLOWPIPE, ETC.—On charcoal, fuses, deflagrates, colors the flame bluish green and gives odor of garlic. Residue is a brown, brittle, somewhat crystalline button. In closed tube, yields water. Soluble in nitric acid.

MALACHITE.—Green Carbonate of Copper.

COMPOSITION.—$Cu_2(OH)_2CO_3$, (CuO 71.9, CO_2 19.9, H_2O 8.2 per cent.)

GENERAL DESCRIPTION.—Bright-green masses and crusts, often with a delicate, silky fibrous structure or banded in lighter and darker shades of green. Sometimes stalactitic. Also in dull-green, earthy masses, and rarely in small, slender, monoclinic crystals. Frequently coating other copper minerals or filling their crevices and seams.

Physical Characters. H., 3.5 to 4. Sp. gr., 3.9 to 4.03.
LUSTRE, silky, adamantine or dull. TRANSLUCENT to opaque.
Streak, pale green. TENACITY, brittle.
COLOR, bright emerald to grass green or nearly black.

BEFORE BLOWPIPE, ETC.—On charcoal, decrepitates, blackens, fuses, and colors the flame green, leaving a globule of metallic copper. In closed tube, blackens and yields water and carbon dioxide. Soluble in acids, with effervescence.

SIMILAR SPECIES.—Distinguished by color and effervescence with acids.

REMARKS.—Malachite is formed by action of carbonated waters on other copper minerals. It is found chiefly with these or pseudomorphous after them, especially after cuprite and azurite. Immense deposits occur at Bisbee, Arizona, and other localities in the same region. Also in large deposits in Siberia, Chili and Australia. In smaller quantities it is found in the vicinity of all copper ores.

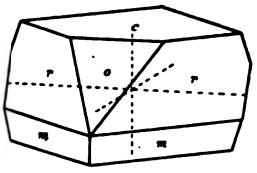
USES.—Is an ore of copper, and like marble is polished for ornamental articles, table-tops, etc.

AZURITE.—Blue Carbonate of Copper.

COMPOSITION.—$Cu_3(OH)_2(CO_3)_2$, (CuO 69.2, CO_2 25.6, H_2O per cent.).

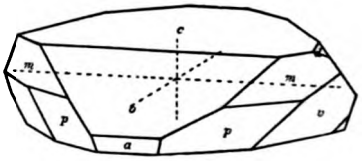
GENERAL DESCRIPTION.—A dark-blue mineral occurring highly modified glassy crystals and groups. When massiv may be vitreous, sometimes velvety or dull and earthy. It quently occurs as an incrustation on other copper ores, and tributed through their cracks and crevices.

Fig. 481.



Arizona.

Fig. 482.



Chessy, France.

CRYSTALLIZATION.—Monoclinic. Axes $\dot{a} : \bar{b} : \dot{c} = 0.850 : 1 : 0.$ $\beta = 87° 36'$.

Crystals very varied in habit. Those figured show basal p coid *c*, ortho pinacoid *a*, unit prism *m*, unit dome *o*, and the p mids *p*, *r*, and *v*. Prominent angles are $mm = 99° 19'$; $co = 135°$ Optically +.

Physical Characters. H., 3.5 to 4. Sp. gr., 3.77 to 3.83.

LUSTRE, vitreous. TRANSLUCENT to opaqu

STREAK, blue. TENACITY, brittle.

COLOR, dark blue to azure blue.

BEFORE BLOWPIPE, ETC.—As for malachite.

REMARKS.—Origin, associates and localities are the same as for malachite.

USES.—As an ore of copper and a rather unsatisfactory b paint.

CHRYSOCOLLA.

COMPOSITION.—$CuSiO_3 + 2H_2O$. Often very impure (CuO 4 SiO_2 34.3, H_2O 20.5 per cent.).

GENERAL DESCRIPTION.—Green to blue incrustations and se often opal-like in texture, or sometimes, from impurities, res bling a kaolin colored by copper. Also brown, resembling limo and in dull green earthy masses. Never found in crystals.

Physical Characters. H., 2 to 4. Sp. gr., 2 to 2.3.
LUSTRE, vitreous, dull. TRANSLUCENT to opaque.
STREAK, white. TENACITY, brittle.
COLOR, green to light blue, brown when ferriferous.

BEFORE BLOWPIPE, ETC.—In forceps or on charcoal is infusible, but turns black, then brown and colors the flame emerald green. In bead, reacts for copper. With soda, yields malleable copper. In closed tube, yields water. Decomposed by hydrochloric acid, leaving a residue of silica. Boiled with KOH, yields a blue solution, from which excess of NH_4Cl precipitates flocculent H_2SiO_3.

SIMILAR SPECIES.—It is softer than turquois or opal and does not effervesce like malachite.

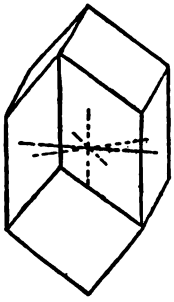
REMARKS.—Chrysocolla occurs with other copper minerals, especially near the tops of veins. It is probably formed by the action of hot solutions of alkaline silicates on other copper ores. Found at Clifton, Arizona; Hartville, Wyoming, and in most of the prominent copper-bearing regions.

USES.—As an ore of copper and an imitation turquois.

DIOPTASE.

COMPOSITION.—H_2CuSiO_4, (CuO 50.4, SiO_2 38.2, H_2O 11.4 per cent.).

FIG. 483.



GENERAL DESCRIPTION.—Glassy, emerald-green crystals and druses of indistinct crystals. Also found massive.

CRYSTALLIZATION.—Hexagonal, $c = 0.534$. $R \wedge R = 125°\ 55'$. $2 \wedge 2 = 95°\ 26\frac{1}{2}'$. Commonly prismatic, with rhombohedral terminations.

PHYSICAL CHARACTERS. Transparent to opaque. Lustre, vitreous Color, emerald green. Streak, green. H, 5. Sp. gr., 3.28 to 3.35. Brittle. Cleavage, rhombohedral.

BEFORE BLOWPIPE, ETC.—Decrepitates, blackens, colors the flame emerald green, but is infusible. In closed tube, blackens and yields water. Gelatinizes with acids.

CHAPTER XXVIII.

MERCURY AND SILVER MINERALS.

THE MERCURY MINERALS.

The minerals described are: *Metal*, MERCURY; *Sulphide*, NABAR; *Chloride*, CALOMEL.

The only ore is cinnabar with which the native metal somet occurs in small quantities. The ore is usually low grade, mined in this country yielding an average of less than one per of mercury. The world's product of mercury in 1898 was a 4,600 tons, of which the United States produced about one-fo or 1,163 tons. In 1899 the output of the United States was 1 tons.*

Mercury is obtained from cinnabar by heating the larger lu in a shaft-furnace, resembling a continuous lime kiln, with t exterior fire places. A little fuel is also mixed with the ore. heat decomposes the sulphide, forming fumes of sulphur dio and mercury. These fumes are carried off through large pipes to condensers where the mercury is liquified. The finer c heated in a vertical shaft containing a series of inclined shelves c which the ore slips whenever any is drawn off at the bottom. fumes go to the condensers already mentioned.

Mercury is extensively used in certain processes for the ex tion of gold and silver from their ores and in the manufactu vermilion. Minor uses are in barometers, thermometers, silve mirrors, and in medicine.

MERCURY.

COMPOSITION.—Hg, with sometimes a little silver.

GENERAL DESCRIPTION.—A tin white liquid with metallic lustre. Usually fou little globules scattered in the gangue, or in cavities with cinnabar or calomel.

PHYSICAL CHARACTERS.—Opaque liquid. Lustre, metallic. Color, tin white. gr., 13.59.

BEFORE BLOWPIPE, ETC.—Entirely volatile. In matrass or closed tube ma collected in small globules. Soluble in nitric acid.

* *Engineering and Mining Journal*, 1900, p. 2.

CINNABAR.—Natural Vermilion.

COMPOSITION.—HgS, (Hg 86.2 per cent.).

GENERAL DESCRIPTION.—Very heavy, bright vermilion to brownish red masses of granular texture; more rarely small transparent rhombohedral crystals, or bright scarlet powder, or earthy red mass. Sometimes nearly black from organic matter.

Physical Characters. H., 2 to 2.5. Sp. gr., 8 to 8.2.

LUSTRE, adamantine to dull. OPAQUE to transparent.

STREAK, scarlet. TENACITY, brittle to sectile.

COLOR, cochineal red, scarlet, reddish brown, blackish.

BEFORE BLOWPIPE, ETC.—Completely volatilized without fusion if pure. With soda gives sulphur reaction. In closed tube yields black sublimate, which becomes red when rubbed; if soda is used a metallic mirror is obtained instead of the black sublimate, and by rubbing with a splinter of wood globules of mercury may be collected. If cinnabar powder is moistened with hydrochloric acid and rubbed on bright copper the coin is coated with mercury. Soluble in aqua regia.

SIMILAR SPECIES.—Cinnabar is softer and heavier than hematite, cuprite, and rutile. It has more decided red streak than crocoite and realgar, and differs from proustite in density and blowpipe reactions.

REMARKS.—Cinnabar occurs in slate rocks and shales, and sometimes in granite or porphyry associated with sulphides of iron, copper, antimony, and arsenic, and with native gold. Its chief localities are Idria, Southern Austria; Almaden, Spain; Huancavelica, Peru; Kwei-chan, China; Ekaterinoslav, Russia, and at several places in Lake, San Benito, Napa, and Santa Clara counties, California

USES.—It is the only important ore of mercury. The artificial cinnabar is the important pigment vermilion.

CALOMEL.—Horn Mercury.

COMPOSITION.—Hg_2Cl_2, (Hg 84.9 per cent.).

GENERAL DESCRIPTION.—A gray or brown translucent mineral of the consistency of horn. Usually found as a coating in cavities with or near cinnabar. Sometimes in well-developed tetragonal forms $\dot{c} = 1.723$.

PHYSICAL CHARACTERS.—Translucent. Lustre, adamantine. Color, gray, white, brown. Streak, white. H., 1 to 2. Sp. gr., 6.48. Very sectile.

BEFORE BLOWPIPE, ETC.—Volatilizes without fusion, yielding a white coating. In closed tube with soda forms a metallic mirror.

THE SILVER MINERALS.

The minerals described are: *Metal*, SILVER, AMALGAM; *phides, Tellurides*, etc., ARGENTITE, HESSITE, PROUSTITE, PY GYRITE, STEPHANITE, POLYBASITE, STROMEYERITE; *Haloids*, CE GYRITE, BROMYRITE, EMBOLITE, IODYRITE.

Generally speaking ordinary silver ores contain less thar per cent. of the silver compounds distributed through va earthy and metallic minerals, and only in occasional rich speci do they show the true nature of the silver-bearing subst Frequently the ore will contain less than twenty ounces of s per ton.

In 1898* the production of silver was 58,763,127 ounc this country alone, and the product of the world was 190,(163 ounces. In 1899 the United States produced 61,179 ounces, valued at $36,573,218.†

A steadily increasing proportion of the world's output of s is obtained from ores of other metals which contain it, espec the ores of lead and copper. In many cases also the silver erals are smelted with these ores, and the silver later sepa from the metallic lead or copper product.

The extraction of silver by reduction with lead-ores in a w jacket furnace, and the subsequent treatment has been referr under lead, p. 241. When silver is a constituent of a co matte it is recovered as a sedimentary product in the electro refining of the copper. It is collected, together with any present, and further purified.

In some instances the silver is extracted from the ore by processes or by treatment with mercury.

Several processes for extracting silver by the use of mer exist, the principle in every case being that mercury will re certain compounds of silver to metal and unite with the silve if mercury is present and some other substance, as iron or co reduces the ore to silver, the mercury will collect it.

The details of amalgamation are in transforming the silver condition in which the mercury can act—for instance, for chlorides by roasting with salt—and in the method of reduc

* *Mineral Industry*, 1899, 289.

† *Engineering and Mining Journal*, 1900, p. 2.

In pan amalgamation, so called, the finely-crushed ore, chloridized when necessary, and mixed to a pulp with water, is charged into a tub-like vessel, with an iron bottom and wooden sides. In this tub or pan there revolves a stirrer, with arms shaped to throw the pulp to the sides, from which it rolls back to the centre. Attached to the arms are grinding shoes, which can be lowered so as to rub on the iron bottom or be raised free from it. The practice will differ in detail, but generally the pulp will be kept hot by steam, and no mercury will be added until the grinding is completed. During the grinding the metallic iron of the bottom and the shoes reduces the silver compound; although chemicals, such as salt, copper sulphate, potassium cyanide, etc., are sometimes added to assist. After the grinding the mercury is added, and the stirring continued until the mercury has collected all the silver. The mass is then run into a larger tub, diluted, the mercury amalgam separated, and, by subsequent distillation, the silver recovered from the mercury.

SILVER.—Native Silver.

COMPOSITION.—Ag, sometimes alloyed with Au, Cu, Pt, Hg, Sb, Bi.

GENERAL DESCRIPTION.—A silver-white, malleable metal, occurring in masses, scales, and twisted wire-like filaments, Fig. 484, penetrating the gangue or flattened upon its surface. Sometimes in isometric crystals, occasionally sharp but more frequently elongated and needle like or in arborescent groups each branch of which is composed of distorted forms in parallel position.

FIG. 484.

Physical Characters. H., 2.5 to 3. Sp. gr., 10.1 to 11.1.

LUSTRE, metallic. OPAQUE.

STREAK, silver white. TENACITY, malleable.

COLOR, silver white, tarnishing brown to nearly black.

BEFORE BLOWPIPE, ETC.—On charcoal, fuses to a white metallic globule. Soluble in nitric or sulphuric acid, but from these it is precipitated as a white curd-like precipitate by hydrochloric acid or salt. The precipitate darkens on exposure to light.

SIMILAR SPECIES.—When tarnished, resembles copper or bismuth, but is distinguished by its silver-white streak from the former and by non-volatilization from the latter.

REMARKS.—Silver may have been formed by the reduction of its ores, as it occ pseudomorphous after them. It is also changed to sulphides by contact with solu sulphides, and into the chloride by salt water. Its associates are the other sil minerals, and galenite, pyrite, stibnite, tetrahedrite, etc.

The most celebrated mines where native silver is obtained are those of Kongsbe in Norway, and Huantaya, Peru. Occurs also in Northern Mexico, in the Michig copper region, in numerous Colorado localities, at Butte, Montana; in Idaho; Arizo and in smaller quantity in other silver-producing regions.

AMALGAM.

COMPOSITION.—Ag_2Hg_3 to $Ag_{86}Hg$.

GENERAL DESCRIPTION.—A brittle, silver-white mineral of bright metallic lust which occurs in imbedded grains and indistinct isometric crystals.

PHYSICAL CHARACTERS.—Opaque, lustre metallic. Color and streak, silver whi H., 3 to 3.5. Sp. gr., 13.75 to 14.1. Somewhat brittle and cuts with a pecul grating noise.

BEFORE BLOWPIPE, ETC.—On charcoal, partially volatilized, leaving malleable silv In closed tube, yields mercury mirror. Soluble in nitric acid.

FIG. 485.

Freiberg, Sax.

ARGENTITE.—Silver Glance.

COMPOSITION.—Ag_2S, (Ag 87.1 per cent.).

GENERAL DESCRIPTION.—A soft black mineral, metallic lustre, which cuts like wax and occurs masses, disseminated grains, or incrusting, also as is metric crystals, the cube, octahedron or dodecahedr being most common and frequently grouped in parall position as in Fig. 485.

Physical Characters. H., 2 to 2.5. Sp. gr., 7.2 to 7.36.

LUSTRE, metallic. OPAQUE.

STREAK, lead gray. TENACITY, very sectile.

COLOR, lead gray to black or blackish gray.

BEFORE BLOWPIPE, ETC.—On charcoal, swells, fuses, yiel fumes of sulphur dioxide, and finally malleable silver. Solub in nitric acid, with separation of sulphur.

SIMILAR SPECIES.—Differs from other soft black minerals cutting like wax and in yielding malleable silver on heating. D fers from cerargyrite in solubility in nitric acid.

REMARKS.—Occurs sparingly with other silver minerals as pure material, but probably the compound of silver so frequently included in galenite, sphalerite, e Large amounts of argentite have been obtained in Nevada, especially from the Co stock lode and the Austin mines. Also in Arizona. It is a common ore in Mexi Chili, Peru and Bolivia.

USES.—It is an ore of silver.

STROMEYERITE.

COMPOSITION.—CuAg S, (Ag 53.1. Cu 31.1 per cent.).

GENERAL DESCRIPTION.—Dark gray metallic masses resembling chalcocite. Rarely twinned orthorhombic crystals.

PHYSICAL CHARACTERS.—Opaque. Lustre, metallic. Color, dark steel gray. Streak, same as color. H., 2.5–3. Sp. gr. 6.2.–6.3.

BEFORE BLOWPIPE, ETC.—Reacts for copper, silver and sulphur.

HESSITE.

COMPOSITION.—$(Ag \cdot Au)_2Te$, grading from hessite, Ag_2Te (Ag 63 per cent.) to petzite, in which there is 20 to 25 per cent. of gold.

GENERAL DESCRIPTION.—Fine-grained, gray, massive mineral, of metallic lustre. Also coarse granular, and in small, indistinct, isometric crystals.

Physical Characters. H., 2 to 2.5. Sp. Gr., 8.3 to 8.6.

LUSTRE, metallic. OPAQUE.

STREAK, black. TENACITY, slightly sectile.

COLOR, between steel gray and lead gray.

BEFORE BLOWPIPE, ETC.—On charcoal, fuses to a black globule, with white silver points on its surface. If powdered and dropped into boiling concentrated sulphuric acid, the acid is colored an intense purple.

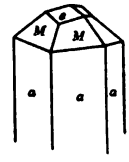
PROUSTITE.—Light Ruby Silver.

COMPOSITION.—Ag_3AsS_3, (Ag 65.4, As 15.2, S 19.4 per cent.). Sometimes containing a little antimony.

GENERAL DESCRIPTION.—A scarlet vermilion mineral, either translucent or transparent, with a scarlet streak. Usually occurs disseminated through the gangue or as a stain or crust. Rarely in small hexagonal crystals.

CRYSTALLIZATION.—Hexagonal. Class of hemimorphic ditrigonal pyramid, p. 42. Axis $\dot{c} = 0.804$. Fig. 486 shows a typical crystal according to Miers. Optically—, with very high indices of refraction ($\gamma = 2.979$ for red light).

FIG. 486.



Physical Characters. H., 2 to 2.5. Sp. gr., 5.57 to 5.64.

LUSTRE, adamantine brilliant. TRANSLUCENT to transparent.

STREAK, scarlet. TENACITY, brittle.

COLOR, scarlet vermilion.

BEFORE BLOWPIPE, ETC.—On charcoal, fuses, yields sulphur and garlic odors and malleable silver. In closed tube, fuses a yields slight red sublimate, yellow when cold. Decomposed nitric acid, leaving a white residue. In powder, is turned black potassium hydroxide solution, and partially dissolved on boili Hydrochloric acid precipitates from this a lemon yellow arse sulphide.

SIMILAR SPECIES.—Differs from pyrargyrite in scarlet stre and from cuprite and cinnabar by garlic odor when heated.

REMARKS.—Occurs with other silver minerals, and is mined as an ore of sil Most abundant in the United States at Poor Man's Lode, Idaho; Austin, Nevada, in Gunnison County, Colorado, at the Ruby silver district; in large quantitie Guanajuato, Mexico; at Chañarcillo, Chili, and other South American locali Noted European localities are Andreasberg, Freiberg, and Joachimsthal in the Ha

PYRARGYRITE.—Dark Ruby Silver.

COMPOSITION.—Ag_3SbS_3, (Ag 59.9, Sb 22.3, S 17.8 per cen Often with small amounts of arsenic.

GENERAL DESCRIPTION.—A nearly black mineral, which is d red by transmitted light and has a purplish-red streak. Usua occurs massive or disseminated, or in thin films, sometimes crystals.

CRYSTALLIZATION.—Hexagonal. Class of hemimorphic ditrigonal pyramid, p. 42. Axis $\dot{c} = 0.789$. Prismatic crystals, with rhombohedral or scalenohedral terminations. Frequently twinned. Fig. 487 shows typical crystal according to Miers. Optically—with very high indices of refraction ($\gamma = 3.084$ for red light).

FIG. 487

Physical Characters. H., 2.5. Sp. gr., 5.77 to 5.86.

LUSTRE, metallic, adamantine. TRANSLUCENT to opaque.

STREAK, purplish red. TENACITY, brittle.

COLOR, black or nearly so, but purple red by transmitted ligh

BEFORE BLOWPIPE, ETC.—On charcoal, fuses easily, spir evolves dense white fumes and leaves malleable silver. A wh sublimate forms. In closed tube, yields black sublimate, r when cold. Soluble in nitric acid, with separation of sulph and antimony trioxide. In powder, is turned black by a soluti of potassium hydroxide, and on boiling it is decomposed; the so

tion deposits an orange precipitate on addition of hydrochloric acid.

SIMILAR SPECIES.—The streak is purplish red differing from the scarlet of proustite. The streak and silver reaction distinguish it from cuprite, cinnabar and realgar.

REMARKS.—Occurs with other silver minerals and with arsenic, arsenopyrite, tetrahedrite, galenite, etc. Localities same as for proustite, with which it is usually associated.

USES.—It is an important ore of silver.

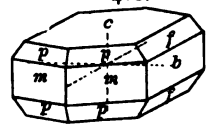
STEPHANITE.—Brittle Silver Ore.

COMPOSITION.—Ag_5SbS_4, (Ag 68.5, Sb 15.2, S 16.3 per cent.).

GENERAL DESCRIPTION.—Fine-grained, iron-black mineral, with metallic lustre, often disseminated through the gangue. Sometimes in short six-sided prismatic crystals. It is soft, but brittle.

CRYSTALLIZATION.—Orthorhombic. Axes $\breve{a} : \bar{b} : \dot{c} = 0.629 : 1 : 0.685$. Short prismatic crystals often twinned in pseudo-hexagonal shapes. Unit pyramid p, unit prism m, the pinacoids b and c and the dome $f = \infty \breve{a} : \bar{b} : 2c$ are the commoner forms. Angles $mm = 115° 39'$; $pp = 130° 16'$; $cf = 126° 7'$.

FIG. 488.



Physical Characters. H., 2 to 2.5. Sp. gr., 6.2 to 6.3.

LUSTRE, metallic. OPAQUE.

STREAK and COLOR, black. TENACITY, brittle.

BEFORE BLOWPIPE, ETC.—On charcoal, fuses easily, yielding white fumes and coat and odor of sulphur dioxide, finally leaves malleable silver. Soluble in nitric acid, with residue of sulphur and antimony trioxide. With potassium hydroxide, reacts like pyrargyrite.

SIMILAR SPECIES.—It is more brittle than argentite and softer than tetrahedrite.

REMARKS.—Occurs with other silver ores. It is of common occurrence in the Nevada silver mines, and also at Guanajuanto, Mexico, and at Chañarcillo, Chili. Found also in the mines of Idaho and in those of Saxony, Bohemia and Hungary.

POLYBASITE.

COMPOSITION.—$(Ag.Cu)_9SbS_6$, often with some Sb replaced by As.

GENERAL DESCRIPTION.—A soft, iron-black mineral, of metallic lustre, best k in six-sided tabular prisms, with bevelled edges. In thin splinters it is cherry r transmitted light. Orthorhombic.

PHYSICAL CHARACTERS.—Nearly opaque. Lustre metallic. Color and s black. H., 2 to 3. Sp. gr., 6 to 6 2. Brittle.

BEFORE BLOWPIPE, ETC.—Fuses with spirting. Gives off odor of garlic some but always yields heavy white fumes and odor of sulphur dioxide, and leaves mal button, which in beads reacts for copper, or, if dissolved in nitric acid, will yi flocculent white precipitate on addition of hydrochloric acid. In closed tube, very easily, but yields no sublimate. Soluble in nitric acid.

CERARGYRITE.—Horn Silver.

COMPOSITION.—AgCl, (Ag 75.3 per cent.).

GENERAL DESCRIPTION.—A soft, grayish-green to violet c or coating of the consistency and lustre of horn or wax. Ra in cubic crystals.

Physical Characters. H., 1 to 1.5. Sp. gr., 5 to 5.5.

LUSTRE, waxy, resinous. TRANSLUCENT.

STREAK, shining white. TENACITY, very sectil

COLOR, pearl gray or greenish, darkens on exposure to li becoming violet, brown or black.

BEFORE BLOWPIPE, ETC.—Fuses very easily, yields acrid fu and a globule of silver. Rubbed on a moistened surface of or iron, it swells, blackens and the surface is silvered, and the eral is reduced to spongy metallic silver. In matrass, with potassium sulphate, yields a globule, yellow hot, white cold, made violet or gray by sunlight. Insoluble in acids, soluble in monia. On coal, with oxide of copper, yields azure-blue flam

SIMILAR SPECIES.—Bromyrite, embolite and iodyrite are n easily distinguished by tests with acid potassium sulphate. differs from argentite in color and insolubility in nitric acid.

REMARKS.—Occurs usually near the top of veins, and is probably precipitated silver-bearing solutions by chlorides in surface waters. In the United States its celebrated localities have been Poor Man's Lode, Horn Silver and certain Idaho m and the mines at Austin, Nevada Found also in proportionally large quantiti many of the Mexican and Chilian mines.

USES.—It is a very important ore of silver.

BROMYRITE.—Bromargyrite.

COMPOSITION.—AgBr, (Ag 57.4 per cent.).

GENERAL DESCRIPTION.—Like cerargyrite, except that the color is bright yellow to grass green or olive green. H., 2 to 3. Sp. gr., 5.8 to 6. Usually found in small concretions and little altered by exposure.

BEFORE BLOWPIPE, ETC.—Like cerargyrite, except that in matrass with acid potassium sulphate a little bromine vapor is evolved, coloring the fluid salt yellow, and the fused bromyrite sinks as a dark red, transparent globule, which, on cooling, becomes opaque and deep yellow, and when exposed to sunlight becomes dark green.

EMBOLITE.

COMPOSITION.—Ag(Cl.Br). Isomorphic mixtures of the chloride and bromide.

GENERAL DESCRIPTION.—Intermediate between cerargyrite and bromyrite. Color, green to yellow, darkening on exposure. H., 1 to 1.5. Sp. gr., 5.31 to 5.81.

BEFORE BLOWPIPE, ETC.—The acid potassium sulphate fusion is like that of cerargyrite or that of bromyrite, as the bromine is small in amount or plentiful.

IODYRITE.—Iodargyrite.

COMPOSITION.—AgI, (Ag 46, I 54 per cent.).

GENERAL DESCRIPTION.—A yellow or yellowish-green, wax-like mineral, occurring massive or in thin flexible scales or in hexagonal crystals.

PHYSICAL CHARACTERS.—Translucent. Lustre, resinous, wax-like. Color, gray, yellow or yellowish green. Streak yellow. H., 1. Sp. gr., 5.6 to 5.7. Sectile.

BEFORE BLOWPIPE, ETC.—Fuses very easily, spreads out and gives pungent odor. In closed tube, fuses and becomes deep orange in color, but cools yellow. With oxide of copper, colors flame intense green. In matrass with acid potassium sulphate, yields violet vapor and deep-red globule, which is yellow when cold and not changed by exposure to sunlight.

CHAPTER XXIX.

GOLD, PLATINUM AND IRIDIUM MINERALS

THE GOLD MINERALS.

THE minerals described are: *Metal*, GOLD; *Tellurides*, SYLV ITE, CALAVERITE, KRENNERITE.

Aside from vein and placer deposits of native gold the met obtained to a very considerable extent from the minerals py arsenopyrite and pyrrhotite, and from other sulphides or telluri In Colorado, for instance, the gold occurs chiefly in pyrite. 1899 there was produced* in the United States 3,506,679 ounces of gold worth $72,483,055 which was nearly one fourt the world's, production of $313,954,468. About three-fourth the total output was used in coinage and the remainder in the a

A large proportion of the world's gold is found in superf deposits called placers, which are beds of sand, gravel or boul accumulated from the erosion of higher rocks containing gold ve In working shallow placers the dirt is thrown into a wooden tro several hundred feet long, through which a stream of wate flowing. At the bottom of the trough or "sluice" are pla cross-bars or blocks of wood, or sometimes a pavement of stones set on edge is constructed. Near the head of the sl mercury is added at a regular rate, and this encountering the g unites with it, and the heavy gold and heavy amalgam are cau in the interstices of the wood or stone pavement, while the ligl material is washed away. At intervals the stream is stopp the bars or blocks removed and the amalgam collected. By h ing in a retort the mercury is distilled from the gold.

Deep placers are sometimes treated by what is called hydra mining, which differs from the preceding chiefly in the magnit of the work and the fact that the water is used in great volume at heavy pressure, not simply to carry the material down the sl but also to tear down and wash away the placer. Frequently is preceded by driving a tunnel into the bottom of the placer exploding heavy charges of powder to loosen the gravel bank.

* *Engineering and Mining Journal*, 1900, p. 2.

Gold that is found in place is usually in quartz veins associated with sulphides, especially pyrite. It is extracted by finely crushing the vein rock and collecting the gold by mercury or copper plates coated with mercury. The vein material is usually stamped in a mortar by blows of several pestles, usually five, raised successively by cams and dropped. Generally water and mercury are in the mortar, and as the material becomes sufficiently fine the water carries it through a screen over a series of amalgamated plates which catch most of the gold. From time to time the amalgam is scraped from the plates and collected from the mortar and retorted.

Gold bearing pyrite is usually stamped as described, but the residues which still carry some gold are frequently concentrated, roasted, and chlorinated. That is, the roasted ore is subjected to the action of chlorine and the gold is converted into a chloride, soluble in water. The chlorine may be generated by a mixture of salt, pyrolusite and sulphuric acid, or by a mixture of sulphuric acid and chloride of lime. After dissolving out the chloride of gold with water the gold may be precipitated as metal by ferrous sulphate or as sulphide by hydrogen sulphide; in the latter case the precipitate is pressed, dried, roasted, and finally fused.

A more recent method is to submit the finely crushed ore, which has previously been roasted, if sulphide or telluride, to a weak solution of potassium cyanide. With the aid of the oxygen of the air, or of some oxidizing agent, the potassium cyanide dissolves the gold. The solution is then drawn off into large vats where the gold is precipitated by means of zinc turnings or the gold may be separated electrolytically. The method has become of the greatest importance and comparatively poor ores and tailings from the amalgamation process are very successfully treated by it.

GOLD.

COMPOSITION.—Au, usually alloyed with Ag, and sometimes Cu, Bi, Rh, or Pd.

GENERAL DESCRIPTION. — A soft malleable metal with color and streak varying from golden yellow to yellowish white according to the silver contents. It is found in nuggets, grains,

FIG. 489.

Butte Co., Colo.

or scales, usually so disseminated as to be apparent only on as
Rarely in distinct isometric crystals, but more frequently in skel
crystals or distorted and passing into wire-like, net-like, and
dritic shapes. Also occurs included in many sulphides, as py
sphalerite, galenite, pyrrhotite, and arsenopyrite.

Physical Characters. H., 2.5 to 3. Sp. gr., 15.6 to 19.3.
LUSTRE, metallic. OPAQUE.
STREAK, like color. TENACITY, malleab
COLOR, golden yellow to nearly silver white.

BEFORE BLOWPIHE, ETC.—On charcoal fuses to a bright ye
button insoluble except in aqua regia. Any silver present will s
rate from the solution as a white curd-like precipitate. If the s
tion is evaporated to a thick syrup and diluted with water
heated with stannous chloride it becomes purple, and a purple
cipitate settles.

SIMILAR SPECIES.—Chalcopyrite, pyrite, and scales of yel
mica are mistaken for gold, but differ entirely in specific gra
streak, brittleness, and solubility in acids.

REMARKS.—Occurs in infinitesimal amount in practically all rocks and soil, and
when in paying quantities is commonly only revealed by an assay. The solvent a
of superheated water collects and redeposits the gold in more concentrated state,
ally in quartz veins associated with or contained in pyrite, arsenopyrite, chalcop
galenite, pyrrhotite, magnetite, hematite, bismuth, tellurium minerals, etc. It is
tically unchangeable, but the wearing away of the containing rocks and the so
and transportation of the fragments with the solution of the solvent portions resu
the formation of gold-bearing gravels, river beds, etc.

The four largest gold producing States are California, Colorado, South Dakota
Montana. Besides these American localities the mines of Victoria and New S
Wales, Australia, those on the eastern coast of South Africa, and the Siberian m
are the largest gold producers. Many other countries yield smaller amounts.

USES.—The chief uses are for coinage and jewelry.

SYLVANITE.—Graphic Tellurium.

COMPOSITION.—$(Au.Ag)Te_2$. Au about 25 per cent.

GENERAL DESCRIPTION.—A soft silver-white or light gray mineral of metallic lu
usually found in flat plate-like monoclinic crystals, which are joined in branching gr
resembling Hebrew letters. Also in bladed and granular masses.

PHYSICAL CHARACTERS.—Opaque. Lustre, metallic. Color, silver white or
gray, inclining to yellow. Streak like color. H., 1.5 to 2. Sp. gr., 7.9 to 8.3.
sectile.

BEFORE BLOWPIPE, ETC.—On charcoal fuses to a gray globule, yields a white s
mate which disappears in reducing flame, coloring the flame green. After long heat

light yellow bead of metal is obtained, which is soluble in aqua regia with a curd-like white precipitate. In open tube yields a white sublimate which melts to clear transparent drops. If powdered and dropped into boiling concentrated sulphuric acid the acid is colored intense purple. Soluble in nitric acid.

CALAVERITE.

COMPOSITION.—$AuTe_2$ with the gold sometimes partly replaced by Ag. Gold about 40 per cent.

GENERAL DESCRIPTION.—A pale yellow, fine grained mineral, with metallic lustre.

PHYSICAL CHARACTERS.—Opaque. Lustre, metallic, color, steel gray to silver white becoming yellow on heating and perhaps also at times from exposure. Streak, like color. H., 2.5. Sp. gr., 9.04.

BEFORE BLOWPIPE, ETC.—As for sylvanite except that the button finally obtained is bright yellow and nearly pure gold.

REMARKS.—Is the chief gold ore of the Cripple Creek, Colo., district.

KRENNERITE.—Is a mineral occurring in orthorhombic crystals and with the same composition as calaverite. It may be the same species.

THE PLATINUM AND IRIDIUM MINERALS.

The minerals described are PLATINUM, and IRIDOSMINE.

Purified platinum is largely used in incandescent lamps, in dental practice for attaching artificial teeth to the plate, in laboratory apparatus, in stills for sulphuric acid and to a more limited extent in jewelry, in electrical contact points, in photography for platinotype prints, in the so-called "oxidizing of silver," and in the balance wheels of non-magnetic watches.

The greater portion of the metal is obtained by washing placer deposits in the Ural mountains, and only a little is obtained from other localities. Russia produced 158,500 ounces in 1896.*

Platinum, as it occurs in nature, is always alloyed with iron and other metals, from which it must be separated before it possesses the peculiar properties which make it valuable. The native mineral is first treated with dilute aqua regia, which dissolves out any iron, gold or copper. Then concentrated aqua regia is added to the residue, and the platinum and a small amount of iridium are brought into solution. After evaporation of the excess of acid, ammonium chloride is added, the ammonium-platinic chloride being formed and also a small amount of the iridium salt. This precipitate, on being heated, leaves the metal, which consists almost wholly of platinum, but also carries a small amount of iridium. The metals can be further separated, but for many purposes this alloy is preferable to the pure platinum.

**Mineral Industry*, 1897.

The mineral iridosmine, which occurs only in small grains used for pointing gold pens, and, by fusion with phosphorus converted into a phosphide of iridium, which is used for point tools and stylographic pens, for draw-plates for gold and sil wire and for knife edges in the most delicate balances.

The phosphide, by heating in a bed of lime, is changed to p iridium, which, alloyed with platinum, is used for the standa of weights and measures.

A process of iridium plating also exists.

PLATINUM.—Native Platinum.

COMPOSITION.—Pt(Fe), usually with small quantities of Rh, Pd, Os, Cu, and nearly always with Fe even as high as one-si of the whole.

GENERAL DESCRIPTION.—A malleable, steel-gray to white me occurring in small grains and nuggets in alluvial sands. V rarely in small cubes.

Physical Characters.	H., 4 to 4.5.	Sp. gr., 14 to 19.
LUSTRE, metallic.		OPAQUE.
STREAK, steel gray.		TENACITY, malleable
COLOR, light steel gray.		Often magnetic.

BEFORE BLOWPIPE, ETC.—Infusible and unaffected by fluxes any single acid. Soluble in aqua regia.

SIMILAR SPECIES.—Heavier than silver and not soluble in nit acid.

REMARKS.—Found in alluvial deposits with other refractory minerals, as gold, i osmine, chromite, corundum, zircon, diamond, etc. Is said to occur in syenite an sometimes found included in masses of chromite or of serpentine. By far the la part of the platinum of commerce is obtained from placer deposits in the U mountains; Borneo, Brazil, and the United States of Colombia also produce sm amounts. It has been identified in many of the gold regions of the United St but only in small quantities, and the quantity annually produced is insignificant.

IRIDOSMINE.

COMPOSITION.—(Ir.Os), sometimes with Rh, Pt, etc.

GENERAL DESCRIPTION.—A tin-white or gray, metallic mineral, very hard heavy, and occurring in irregular, flattened grains and hexagonal plates.

PHYSICAL CHARACTERS.—Opaque. Lustre metallic. Color and streak, tin wh or gray. H., 6 to 7. Sp. gr., 19.3 to 21.1. Rather brittle.

BEFORE BLOWPIPE, Etc.—Infusible. May yield unpleasant, pungent odor. In uble in acids.

CHAPTER XXX.

POTASSIUM, SODIUM AND AMMONIUM MINERALS.

THE POTASSIUM MINERALS.

THE minerals described are: *Chloride*, SYLVITE; *Sulphates*, APHTHITALITE, KALINITE, KAINITE; *Nitrate*, NITRE. In addition to these, potassium is a constituent of many silicates, among which orthoclase is prominent. It is also found in solution in many brines.

The natural potash salts, especially the chlorides, are obtained in large amounts from two or three deposits in Germany. The present annual output of the syndicate controlling these mines is said to be 3,000,000 tons* and it is estimated that at this rate of production the beds will last for thirty-three centuries. The nitrate is mined in India, and occurs in small amounts elsewhere. Potassium bromide is extracted from the mother liquor of certain brines. The chief important uses are in the form of the nitrate in gunpowder and as the chloride or sulphate in fertilizers. The element is essential to plant growth and is liable to exhaustion in soils.

SYLVITE.

COMPOSITION.—KCl, (K 52.4 per cent.).

GENERAL DESCRIPTION.—Colorless, transparent cubes or white masses, which look like common salt and have somewhat similar taste. Absorbs moisture and becomes damp.

PHYSICAL CHARACTERS.—Transparent when pure. Lustre, vitreous. Color, colorless white, bluish, reddish. Streak, white. H., 2. Sp. gr., 1.97 to 1.99. Taste, like salt. Cleavage in cubes.

BEFORE BLOWPIPE, ETC.—Fuses very readily, coloring flame violet. If added to a salt of phosphorus and copper oxide bead, the flame is colored azure blue. Soluble in water and acids.

APHTHITALITE.

COMPOSITION.—$(K.Na)_2SO_4$.

GENERAL DESCRIPTION.—Thin, white, hexagonal plates or white crusts and masses on lava or with other potassium and sodium minerals. Not altered by exposure.

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* *The Mineral Industry* 1898, p. 553.

PHYSICAL CHARACTERS.—Transparent to opaque. Lustre, vitreous. Color, w
or bluish to greenish. Streak, white. H., 3 to 3.5. Sp. gr., 2.63 to 2.65. T
salt and bitter.

BEFORE BLOWPIPE, ETC.—Fuses easily and quietly, coloring the flame violet. A
fusion on coal in reducing flame, the mass will stain bright silver. Soluble in wa

KALINITE.—Potash Alum.

COMPOSITION.—$KAl(SO_4)_2 + 12H_2O$, (K_2O 9.9, Al_2O_3 10.8, S
33.8, H_2O 45.5 per cent.).

GENERAL DESCRIPTION.—A white efflorescence on argillace
minerals, usually fibrous, or as mealy crusts, or compact.

Physical Characters. H., 2.5. Sp. gr., 1.75.

LUSTRE, vitreous. TRANSPARENT or translucent
STREAK, white. TENACITY, brittle.
COLOR, white. TASTE, astringent.

BEFORE BLOWPIPE, ETC.—On heating, becomes liquid, yie
water, and finally swells to a white, spongy, easily-powdered m
which is infusible, but colors the flame violet. With cobalt so
tion, becomes deep blue on heating. Soluble in water.

KAINITE.

COMPOSITION.—$MgSO_4.KCl + 3H_2O$.

GENERAL DESCRIPTION.—White to dark red granular crusts with salty taste,
tabular and prismatic monoclinic crystals.

PHYSICAL CHARACTERS.—Transparent to translucent. Color, white to reddish w
and colorless. Lustre, vitreous. Streak, colorless. Taste, salty and astringent.
2.5–3. Sp. gr., 2.05–2.2.

BEFORE BLOWPIPE, ETC.—Easily fusible. Colors, flame violet. After fusio
charcoal in reducing flame the moistened mass will stain bright silver. Solubl
water.

REMARKS.—Occurs in beds of considerable thickness in Germany, with halite,
vite, and other soluble salts.

NITRE.—Saltpetre.

COMPOSITION.—KNO_3, (K_2O 46.5, N_2O_5 53.5 per cent.).

GENERAL DESCRIPTION.—White crusts, needle-like, orthorh
bic crystals and silky tufts, occurring in limestone caverns o
incrustations upon the earth's surface or on walls, rocks, etc.
altered by exposure.

Physical Characters. H., 2. Sp. gr., 2.09 to 2.14.

LUSTRE, vitreous.	TRANSLUCENT.
STREAK, white.	TENACITY, brittle.
COLOR, colorless, white, gray.	TASTE, salty and cooling.

BEFORE BLOWPIPE, ETC.—On charcoal fuses easily, deflagrates violently like gunpowder, colors the flame violet. Soluble in water.

REMARKS.—Formed in certain soils by the action of a ferment, especially after rains. Although found in small quantity in many of the so-called alkali lands of our Western States, it is not utilized. Deposits in Ceylon and India are worked, and refined nitre produced, but almost all of the commercial product is made from sodium nitrate and potassium chloride.

THE SODIUM MINERALS.

The minerals described are: *Chloride*, HALITE; *Sulphates*, THENARDITE, GLAUBERITE, MIRABILITE; *Carbonates*, Trona, GAY-LUSSITE; *Nitrate*, SODA NITRE, besides which sodium is an important constituent in certain silicates.

The most important of these minerals are halite, soda-nitre and trona.

HALITE is common salt. It occurs in various localities in beds varying from a few feet to over three thousand feet in thickness. It occurs also in nearly all water, from infinitesimal quantities to strong brines, and it occurs as incrustations on high planes in dry regions. The salt deposits are mined and the brines are pumped up and evaporated by the heat of the sun or by artificial heat. In this country 19,025,794 barrels were reported * as produced in 1899.

The amount used is enormous; for instance, over 1,000,000 tons per year are converted into sodium and chlorine compounds, chief among which are sodium carbonate and bicarbonate, caustic soda and bleaching powder.

SODA NITRE is found in enormous quantities at Tarapaca, Chili; nearly a million tons a year are exported. It is used in the manufacture of nitre for gunpowder, in the production of nitric acid, but chiefly for fertilizing purposes.. It is also the source of most of the iodine as the mother liquors after refining may contain twenty per cent. of sodium iodate.

* *Engineering and Mining Journal*, 1900, p. 2.

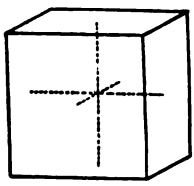
TRONA.—Carbonates of sodium, mixed carbonates, and bic
nates occur plentifully in the alkali deserts of the West wit
phates and chlorides. The pools and lakes into which thes
tricts drain contain large amounts of these salts, and by evapo
the water to the required degree of concentration, crystals o
are deposited, which are refined by subsequent operations.

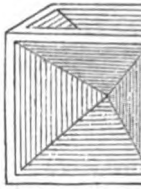
HALITE.—Rock Salt, Common Salt.

COMPOSITION.—NaCl, (Na 60.6 per cent.), usually impure

GENERAL DESCRIPTION.—Essentially colorless to white
vitreous, but from iron is frequently brown to red. It occu
cubic crystals, often with cavernous faces and in masses,
cubical cleavage, and also compact granular and coarse fi
In dry countries it occurs as a fibrous efflorescence. It is
to absorb moisture and becomes damp, especially when conta
calcium or magnesium chlorides. It is known by its taste.

FIG. 490. FIG. 491. FIG. 492. FIG. 493





Physical Characters. H., 2.5. Sp. gr., 2.4 to 2.6.

LUSTRE, vitreous. TRANSLUCENT to transpare
STREAK, white. TENACITY, brittle.
COLOR, white, colorless, yellow, brown, deep blue.
TASTE, salt. CLEAVAGE, cubic.

BEFORE BLOWPIPE, ETC.—Decrepitates violently, fuses
easily and colors the flame yellow and may be volatilized. E
soluble in cold water.

SIMILAR SPECIES.—The taste distinguishes it from all
minerals.

REMARKS.—Halite occurs with rocks of all ages in beds of great thickness.
are formed by the gradual and complete evaporation of bodies of water into whi
salt has been brought in small increments by inflowing streams. Vast lakes an
of salt water exist in different parts of the world as well as many salt springs.

Innumerable immense deposits of salt are known and worked in almost
civilized country. In the United States we have many deposits. Hundreds of

miles of central and western New York are underlaid by strata of salt varying from a few feet to one or two hundred feet in thickness. Immense amounts of salt are also produced in the Saginaw district of Michigan. At Petite Anse, La., salt is found of such purity and so near the surface that it is simply blasted out and crushed to make it ready for the table. The supply seems to be inexhaustible. In the southeastern part of Nevada a large mountain consists mainly of salt. Many other States also produce this substance, notably, Kansas, West Virginia, Ohio, and California.

The associates are other minerals produced in the same manner, as gypsum, anhydrite and various soluble chlorides, bromides and sulphates.

USES.—Halite is the source of all the salt of commerce and of most of the sodium and sodium compounds. It is used to glaze pottery, and in many chemical and metallurgical processes.

THENARDITE.

COMPOSITION.—Na_2SO_4 (Na_2O 56.3 per cent.).

GENERAL DESCRIPTION.—White or brownish orthorhombic crystals in salt beds, either acute pyramids or short tabular prisms with rough faces. Also massive and as an efflorescence or incrustation in alkali lands.

PHYSICAL CHARACTERS.—Transparent to translucent. Lustre, vitreous. Color, white or brownish. Streak, white. H., 2 to 3. Sp. gr., 2.68 to 2.69. Taste, salt and bitter.

BEFORE BLOWPIPE, ETC.—On charcoal fuses to a mass which will stain bright silver. Colors flame yellow. Soluble in water.

FIG. 494.

Thenardite.
Borax Lake, Cal.

FIG. 495.

Glauberite.
Borax Lake, Cal.

GLAUBERITE.

COMPOSITION.—$Na_2SO_4.CaSO_4$ (Na_2O 22.3, CaO 20.1, SO_3 57.6 per cent.).

GENERAL DESCRIPTION.—Tabular monoclinic crystals of pale yellow, green, or red color, occurring in beds of rock salt, also in lamellar masses. On long exposure it absorbs moisture and falls to powder.

PHYSICAL CHARACTERS.—Translucent. Lustre, vitreous. Color, colorless, yellow, gray or red. Streak, white. H., 2.5 to 3. Sp. gr., 2.7 to 2.85. Taste, bitter and slightly salt.

BEFORE BLOWPIPE, ETC.—On charcoal decrepitates, whitens, colors flame yellow, fuses to a bead, clear hot, opaque cold, which when moistened will stain bright silver. Partially soluble in water, falling to powder.

MIRABILITE.—Glauber Salt.

COMPOSITION.—$Na_2SO_4 + 10H_2O$, (Na_2O 19.3, SO_3 24.8, H_2O 55.9 per cent.).

GENERAL DESCRIPTION.—Translucent, white, fibrous crusts or monoclinic crys closely resembling those of pyroxene in form and angle. On exposure loses water falls to powder.

PHYSICAL CHARACTERS.—Transparent to opaque. Lustre, vitreous. Color and streak white. H., 1.5 to 2. Sr. gr., 1.48. Taste, salty and bitter.

BEFORE BLOWPIPE, ETC.—On charcoal fuses, colors the flame yellow and leav mass which will stain bright silver. In closed tube yields much water. Easily sol in water.

SODA NITRE.—Chili Saltpetre.

COMPOSITION.—$NaNO_3$, (Na_2O 36.5, N_2O_5 63.5 per cent.).

GENERAL DESCRIPTION.—Rather sectile granular masses or cru of white color, occurring in enormous beds and as an efflorescen Rarely found as rhombohedral crystals of the forms of calcite. exposure crumbles to powder.

Physical Characters. H., 1.5 to 2. Sp. gr., 2.24 to 2.29.

LUSTRE, vitreous. TRANSPARENT.

STREAK, white. TENACITY, brittle.

COLOR, colorless, white or yellowish. TASTE, cooling and sa

BEFORE BLOWPIPE, ETC.—On charcoal deflagrates less violen than nitre and becomes liquid. Colors the flame yellow. V easily soluble in water.

REMARKS.—It is associated with salt, gypsum, and many soluble salts. The only one producing locality, the celebrated nitrate fields of northern Chili. These fi however, form one of the greatest sources of wealth to that nation. Smaller dep exist in Nevada, New Mexico, and California. Large deposits are reported in United States of Colombia.

USES.—It is used in manufacture of nitre and nitric acid in la amounts, and also in fertilizers. It frequently contains sodi iodate and is the chief source of the iodine of commerce.

TRONA.—Urao.

COMPOSITION.—$Na_2CO_3 \cdot NaHCO_3 + 2H_2O$, ($Na_2O$ 41.2, CO_2 38.9, H_2O 19.9.)

GENERAL DESCRIPTION.—Beds and thin crusts of white glistening material, c fibrous and occasionally in monoclinic crystals. It is not altered in dry air.

PHYSICAL CHARACTERS.—Translucent. Lustre, vitreous, glistening. Color, wh gray, yellowish. Streak, white. H, 2.5 to 3. Sp. gr., 2.11 to 2.14. Taste, alkal

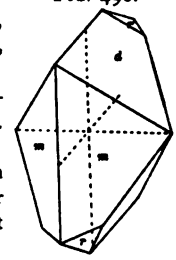
BEFORE BLOWPIPE, ETC.—Fuses easily, coloring flame yellow. In closed yields water and carbon dioxide. Easily soluble in water. Effervesces vigoro in cold dilute acids.

GAY-LUSSITE.

COMPOSITION.—$Na_2CO_3.CaCO_3.5H_2O$.

GENERAL DESCRIPTION.—White monoclinic crystals, Fig. 496, found disseminated in beds of salt lakes, especially at Soda Lake, Nevada, and in Venezuela.

FIG. 496.



PHYSICAL CHARACTERS.—Translucent. Color, white to yellowish. Lustre, vitreous. Streak, colorless. Brittle. H., 2–3. Sp. gr., 1.93–1.99.

BEFORE BLOWPIPE, ETC.—Fuses easily. Is partly soluble in water giving alkaline solution. Effervesces in HCl. Yields water in closed tube. Gives sodium color in Bunsen burner flame but the spectroscope will also show plainly the calcium lines.

THE AMMONIUM MINERALS.

The minerals described are: *Chloride*, SAL AMMONIAC; *Sulphate*, MASCAGNITE.

The hypothetical compound radical ammonium, has never been separated from its compounds. Its occurrence in nature is rare, and its minerals while of great theoretical interest do not occur in commercial quantities. Its compounds, many of which are of great importance in the arts, are obtained by the dry distillation of organic matter, and notably of bituminous coal in the process of gas manufacture, from coke ovens, from the dry distillation of bones and from the gases of blast furnaces using coal as fuel.

SAL AMMONIAC.

COMPOSITION.—NH_4Cl, (NH_4 33.7, Cl 66.3 per cent.).

PHYSICAL CHARACTERS.—Transparent to translucent. Lustre, vitreous. Color, colorless, white, yellowish. Streak, white. H., 1.5 to 2. Sp. gr., 1.53. Taste, pungent, salt. Cleavage, parallel to octahedron.

BEFORE BLOWPIPE, ETC.—Sublimes, without fusion, as white fumes. With soda or quicklime, gives odor of ammouia. Easily soluble in water.

REMARKS.—Occurs near volcanoes, burning coal-beds and in guano deposits. Artificially, it is a by-product from gas-works.

MASCAGNITE.

COMPOSITION.—$(NH_4)_2SO_4$, ($(NH_4)_2O$ 39.4, SO_3 60 6 per cent.).

GENERAL DESCRIPTION.—Yellowish, mealy incrustations on lava or in guano. Rarely in orthorhombic crystals.

PHYSICAL CHARACTERS.—Translucent. Lustre, dull or vitreous. Color, lemon-yellow, yellowish or gray. Streak, white. H., 2 to 2.5. Sp. gr., 1.76 to 1.77. Taste, pungent and bitter.

BEFORE BLOWPIPE, ETC.—Sublimes without fusion. With soda or quicklime, yields odor of ammonia. Easily soluble in water.

REMARKS.—Occurs on lava or guano or near burning coal-beds. It is artificially made from the ammoniacal liquors of gas-works, coke-ovens, and blast furnaces and to a less extent is a by product from the manufacture of boric acid in Tuscany.

CHAPTER XXXI.

BARIUM AND STRONTIUM MINERALS.

THE BARIUM MINERALS.

THE minerals described are: *Sulphate*, BARITE; *Carbon* WITHERITE, BARYTOCALCITE, and the metal occurs also in a silicates.

In the elementary state barium is unimportant. It may be pared by the electrolysis of its chloride. The only impor mineral compound is the sulphate, which is used as an adulte in paint. The mineral is crushed coarsely, treated with sulph acid to remove impurities, washed, pulverized and either mixed white lead or used for giving weight and glaze to paper. Ne 30,000 tons were mined in this country in 1892. The carbo is used in sugar refining.

BARITE.—Heavy Spar.

COMPOSITION.—$BaSO_4$, (BaO 65.7, SO_3 34.3 per cent.), so times with some strontia, silica, clay, etc.

GENERAL DESCRIPTION.—A heavy white or light-colored m eral, vitreous in lustre. It occurs in orthorhombic crystals, wh are frequently united by their broader sides in crested diverg groups, and varying insensibly from this to masses made up curved or straight lamellæ and cleavable into rhombic plates. occurs also granular, fibrous, earthy, stalactitic and nodular.

FIG. 497.

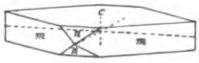


FIG. 498.

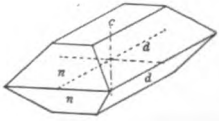


FIG. 499.

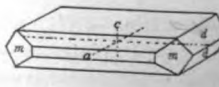


FIG. 500.

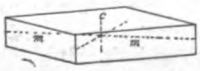


FIG. 501.

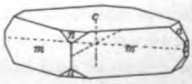
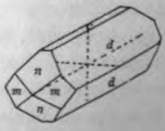


FIG. 502.



CRYSTALLIZATION.—Orthorhombic. Axes $\dot{a} : \bar{b} : \dot{c} = 0.815 : 1 : 1.314$.

Unit prism m, base c and domes $d = \infty \dot{a} : \bar{b} : c$ and $n = \dot{a} : \infty \bar{b} : \frac{1}{2}c$ are most common forms. Angles are $mm = 101° 37'$; $cd = 127° 17'$; $cn = 141° 8'$.

Optically +. The axial plane parallel b and the acute bisectrix normal to a. Axial angle with yellow light $2E = 63° 12$.

Physical Characters. H., 2.5 to 3.5. Sp. gr., 4.3 to 4.6.
LUSTRE, vitreous and pearly. TRANSPARENT to opaque.
STREAK, white. TENACITY, brittle.
COLOR, white or light shades of yellow, brown, red or blue.
CLEAVAGE, basal and prismatic (101° 37′ being prism angle).

BEFORE BLOWPIPE, ETC—In forceps, decrepitates and fuses, coloring the flame yellowish-green and leaving an alkaline residue. With soda, on charcoal, gives sulphur reaction. Insoluble in acids.

SIMILAR SPECIES.—Distinguished among non-metallic minerals by its high specific gravity, insolubility and green flame.

REMARKS.—Usually found with metallic ores, especially of lead, copper, iron, silver, manganese and cobalt. The important American localities producing barite are Hot Springs, N. C., Lynchburg, Va., and Washington Co., Mo. Tennessee, Connecticut, Kentucky and Illinios also have extensive deposits. Some barite is also imported from abroad, Germany and Hungary both having important mines.

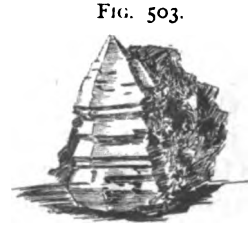
USES.—The white variety is ground and used as an adulterant of white lead and for weighting paper. Colored varieties are sometimes used in ornamental slabs, vases, etc.

WITHERITE.

COMPOSITION.—$BaCO_3$, (BaO 77.7, CO_2 22.3 per cent.).

GENERAL DESCRIPTION.—Heavy white or gray translucent masses of vitreous lustre, sometimes with cavities of indistinct crystals or of globular or botryoidal groups. Also granular, columnar and in six-sided crystals resembling quartz.

FIG. 503.



Cumberland, Eng.

CRYSTALLIZATION.—Orthorhombic. Axes $\dot{a} : \bar{b} : \dot{c} = 0.603 : 1 : 0.730$. Crystals always repeated twins resembling hexagonal pyramids with usually horizontal striations or deep grooves on the faces. Optically —.

Physical Characters. H., 3 to 4. Sp. gr., 4.29 to 4.35.
LUSTRE, vitreous. TRANSLUCENT.
STREAK, white. TENACITY, brittl
COLOR, white, gray, yellowish.

BEFORE BLOWPIPE, ETC.—Fuses rather easily, coloring fl yellowish-green and becoming alkaline. Soluble in dilute hy chloric acid, with effervescence, and less rapidly soluble in str acid.

SIMILAR SPECIES.—Distinguished by its weight, effervesce with acids and green flame.

REMARKS.—Occurs in veins with lead ores or with ores of silver or barite, a probably deposited from solution in water containing carbonic acid. Witherite i mined in the United States, although small deposits occur near Lexington, Ky., on the north shore of Lake Superior. The most productive mines are at Fallow in England.

USES.—As an adulterant of white lead and in refining beet-su molasses.

BARYTOCALCITE.

COMPOSITION.—$BaCa(CO_3)_2$, (BaO 51.5, CaO 18.9, CO_2 29.6 per cent.), with t of manganese.

GENERAL DESCRIPTION.—Occurs massive and in attached monoclinic crystals, ally of a yellowish-white color.

PHYSICAL CHARACTERS.—Translucent. Lustre, vitreous, Color, white, gray lowish, greenish. Streak, white. H., 4. Sp. gr., 3.64 to 3.66. Brittle.

BEFORE BLOWPIPE, ETC.—Fuses with difficulty to a bluish-green mass; colo flame yellowish-green. Soluble in dilute acids, with effervescence.

THE STRONTIUM MINERALS.

The minerals described are: *Sulphate*, CELESTITE; *Carbon* STRONTIANITE.

The strontium minerals are chiefly of use as precipitants sugar from the molasses residues of the beet sugar industry, in the manufacture of the nitrate for use in red fire of firework

CELESTITE.

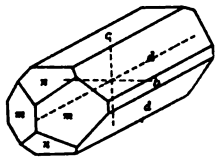
COMPOSITION—$SrSO_4$, (SrO 56.4, SO_3 43.6 per cent.).

GENERAL DESCRIPTION.—A white translucent mineral, often a faint bluish tinge. Occurs in tabular to prismatic orthorhon crystals, fibrous and cleavable masses, and rarely granular. notably heavy, and has a general resemblance to barite.

CRYSTALLIZATION.—Orthorhombic. Axes $\dot{a} : \bar{b} : \dot{c} = 0.779 : 1 : 1.280$.

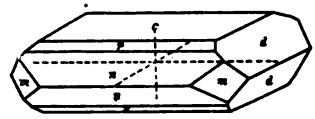
The common forms are the base *c*, the unit prism *m* and the domes *n* and *o*. The angles are $mm = 104° 10'$; $cn = 140° 35'$; $co = 128°$.

FIG. 504.



Sicily.

FIG. 505.



Lake Erie.

Optically +. Axial plane *b*. Acute bisectrix normal to *a*. Axial angle with yellow light $2E = 88° 38'$.

Physical Characters. H., 3 to 3.5. Sp. gr., 3.95 to 3.97.

LUSTRE, vitreous or pearly. TRANSPARENT, nearly opaque.

STREAK, white. TENACITY, brittle.

COLOR, white colorless, pale blue or reddish.

CLEAVAGE.—Basal and prismatic, yielding rhombic plates in which the rhomb angles are 104° 10′ and 75° 50′.

BEFORE BLOWPIPE, ETC.—Fuses easily to a white pearly glass and colors the flame crimson. Usually decrepitates and becomes alkaline. With soda on charcoal gives sulphur reaction. Insoluble in acids.

SIMILAR SPECIES.—Distinguished from barite by its red flame and from other minerals by its high specific gravity, insolubility and red flame.

REMARKS.—Celestite occurs frequently in cavities in limestone, marl or sandstone or with beds of gypsum or in volcanic regions with sulphur, gypsum, etc. The island of Sicily contains the most celebrated deposits of this mineral, and is the chief producing locality. In the United States deposits occur on Strontian and N. Bass Island, Lake Erie, at Bell's Mills, Pa., at Chaumont Bay, Lockport, and other places in western New York. In Kansas, Texas, West Virginia and Tennessee, also at Kingston, Canada.

USES.—It is a source of strontium nitrate used to make crimson color in fireworks.

STRONTIANITE.

COMPOSITION.—$SrCO_3$, (SrO 70.1, CO_2 29.9 per cent.).

GENERAL DESCRIPTION.—Usually found as yellowish-white greenish-white masses made of radiating imperfect needle cryst and spear-shaped crystals, very like those of aragonite. A fibrous or granular and only rarely in distinct orthorhombic cr tals, sometimes of considerable size.

Physical Characters. H., 3 to 3.5 Sp. gr., 3.68 to 3.72.

LUSTRE, vitreous. TRANSLUCENT.

STREAK, white. TENACITY, brittle

COLOR, pale yellowish or greenish-white, also green, gray a colorless.

BEFORE BLOWPIPE, ETC.—In forceps swells, sprouts, colors flame crimson, fuses on the edges and becoming alkaline. Solu in cold dilute acids with effervescence.

SIMILAR SPECIES.—Differs from calcite and aragonite in fusibil higher specific gravity and purer red flame. The flame and ef vescence distinguish it from all other minerals.

REMARKS.—Strontianite is found in the United States chiefly in the State of N York, especially at Schoharie, Muscalonge Lake, Chaumont Bay, Theresa and Clin Strontianite used in the German beet sugar industry is largely obtained from W phalia.

USES.—It is the chief source of the strontium salts used in fi works, and is also converted into the hydroxide and used to p cipitate sugar from molasses as a strontium compound from wh crystalline sugar can later be obtained.

CHAPTER XXXII.

CALCIUM AND MAGNESIUM MINERALS.

THE CALCIUM MINERALS.

The minerals described are: *Fluoride*, FLUORITE; *Sulphates*, ANHYDRITE, GYPSUM; *Phosphate*, APATITE; *Arsenate*, PHARMACOLITE; *Carbonates*, ARAGONITE, CALCITE, DOLOMITE, ANKERITE; *Tungstate*, SCHEELITE; *Titanate*, PEROVSKITE.

Massive calcite and dolomite, that is limestone and marble, are quarried in enormous quantities, the production of limestone exceeding in value even that of granite.

In 1889 there was produced in this country* 3,320,213 cubic feet of marble, while of limestone the production was: for building, 92,289,896 cu. feet; for furnace flux, 3,894,337 tons; for burning, 478,082 tons; for roads, 46,491,622 cu. feet; for other purposes, 27,228,887 cu. feet; lime in addition to above, 18,474,678 barrels.

In addition to uses above enumerated must be given lithographic stone and limestone used for hydraulic cements. In 1899† 10,048,447 barrels of hydraulic cement were produced in the United States.

Gypsum to the amount of 348,686 tons was mined in this country in 1898, of which about three quarters was burned to produce plaster of Paris, and the remainder is simply ground and used as land plaster or sold in the crude state..

Apatite and phosphate rock are used in enormous quantities for the manufacture of soluble phosphates for fertilizers. Florida, South Carolina and Tennessee produced 1,738,372 long tons of phosphate rock‡ in 1899. The phosphoric acid is rendered available for the use of plants by treating the rock with sulphuric acid.

Fluorite has an increasing use as a flux in melting iron and

* *Mineral Industries*, 11th Census, p. 61.

† *Engineering and Mining Journal*, 1900, p. 2.

‡ *Engineering and Mining Journal*, 1900, p. 2.

other metallurgical operations. It is also used in produ
opalescent glass and enamels and in the manufacture of hy
fluoric acid. In 1899§ 24,170 tons were mined in the U
States.

FLUORITE.—Fluor Spar.

COMPOSITION.—CaF_2, (Ca 51.1, F 48.9 per cent.).

GENERAL DESCRIPTION.—Usually found in glassy transpa
cubes or cleavable masses of some decided yellow, green, pu
or violet color. Less frequently granular or fibrous. Mas
varieties are often banded in zigzag strips of different colors.

FIG. 506.

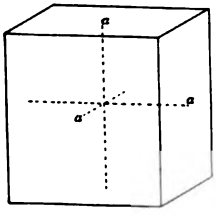


FIG. 507.

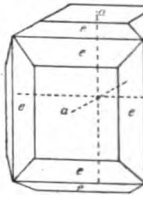
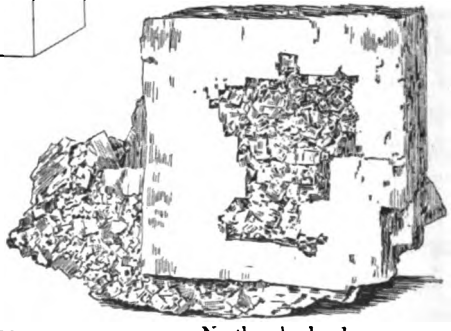


FIG. 508.



Northumberland.

FIG. 509.

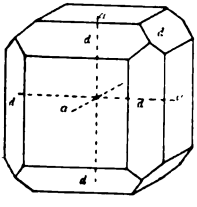
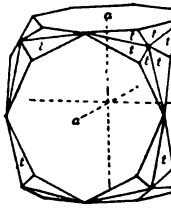


FIG. 510.



CRYSTALLIZATION.—Isometric. Usually cubes with modif
forms, especially the tetrahexahedron $c = a : 2a : \infty a$, the doc
hedron d and the hexoctahedron $t = a : 2a : 4a$. The cube
are often striated parallel to the edges, giving the appearance
very flat tetrahexahedron. Rarely found in octahedrons, s

§ *Engineering and Mining Jornal*, 1900, p. 2.

times formed by the grouping of small cubes in parallel positions. Penetration twins common, Fig. 240.

Index of refraction for yellow light 1.4339.

Physical Characters. H., 4. Sp. gr., 3.01 to 3.25.
LUSTRE, vitreous. TRANSPARENT to nearly opaque.
STREAK, white. TENACITY, brittle.
COLOR, wine-yellow, green, violet, blue, colorless, brown, black. CLEAVAGE, octahedral.

BEFORE BLOWPIPE, ETC.—In closed tube at a low heat becomes phosphorescent. In forceps fuses to a white opaque glass and colors the flame red. Soluble in hydrochloric acid. Heated with acid potassium sulphate or sulphuric acid, fumes are set free which corrode glass.

SIMILAR SPECIES.—Recognized by cleavage and crystals and by the etching test. When cut it may resemble aqua marine, yellow topaz, etc., but is distinguished by softness.

REMARKS.—Fluorite may have been deposited from solution in carbonated waters. It is usually found in veins as the gangue of metallic ores, especially lead, silver, copper, and tin. Sometimes found in beds. This mineral is mined in large quantities at Rosiclare, Illinois. Found in smaller amounts in Jefferson and Boulder counties, Colo.; at McComb and other places in western New York. In many localities throughout New England, also in New Jersey, Arizona, Virginia, California and other States.

USES.—It is used as a flux in smelting ores; also in the manufacture of opalescent glass, hydrofluoric acid, enamel for cooking utensils, and the brighter colored varieties are cut into vases, figures or imitation gems. Used in small amounts as a constituent of the bath used in the electrolytic production of aluminium.

ANHYDRITE.

COMPOSITION.—$CaSO_4$, (CaO 41.2, SO_3 58.8 per cent.).

GENERAL DESCRIPTION.—Granular, marble-like or sugar-like in texture, or as fibrous and lamellar masses of white, gray, bluish or reddish color. Cleavage in three directions at right angles. Rarely in orthorhombic crystals.

Physical Characters. H., 3 to 3.5. Sp. gr., 2.9 to 2.98.
LUSTRE, vitreous or pearly. TRANSLUCENT to opaque.
STREAK, white. TENACITY, brittle.
COLOR, white, gray, bluish, brick-red. CLEAVAGES at right angles.

BEFORE BLOWPIPE, ETC.—Fuses to a white enamel and co the flame red. With soda yields a sulphur reaction. Sol slowly in acids.

SIMILAR SPECIES.—Differs from gypsum in being harder not yielding decided test for water. Does not effervesce in a like marble. Cleavage pseudo-cubic.

REMARKS.—Anhydrite occurs with rock salt, limestone, or with gypsum, which it may have been formed by heat. It changes to gypsum by hydration, with swelling or efflorescence. The chief American locality is at Hillsboro, Brunswick. Also abundant in Nova Scotia. Found in smaller quantity at Lock N. Y., in eastern Pennsylvania and in Tennessee.

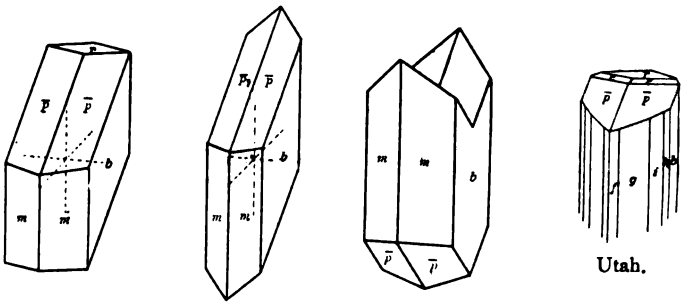
USES.—A siliceous variety is cut and polished for orname work. Its tendency to swell prevents its use in building.

GYPSUM.—Selenite, Alabaster.

COMPOSITION.—$CaSO_4 + 2\,H_2O$, (CaO 32.5, H_2O 20.9, SO_3 per cent.).

GENERAL DESCRIPTION.—Soft colorless white or slightly ti masses, which may be granular or compact, or may be translu and silky, fibrous or transparent and cleavable into plates and st Also in transparent cleavable monoclinic crystals.

FIG. 511. FIG. 512. FIG. 513. FIG. 514



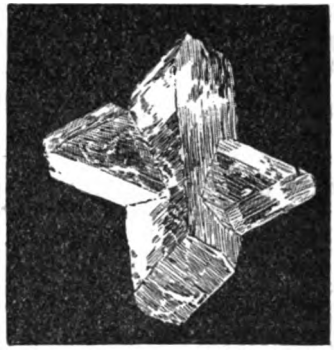
Utah.

CRYSTALLIZATION.—Monoclinic. $\beta = 80°\ 42'$. Axes $\dot{a} : \dot{b}$ $= 0.690 : 1 : 0.412$.

Frequently combination of negative unit pyramid $\bar{p}$, unit pr m and clino pinacoid b, Fig. 512, or these twinned, Fig. 513 with dome $r = \dot{a} : \infty\ \dot{b} : \frac{1}{3}\ c$, Figs. 511 and 514. Angles mm $111°\ 30'$; $\bar{p}\bar{p} = 143°\ 48'$; $cr = 168°\ 31'$.

Optically +. Axial plane at ordinary temperature *b*, but with higher temperatures the axial angle diminishes and the axes pass into a plane at right angles to *b*, the axes for red light so passing at about 120° C., those for yellow light at about 135° C., and the others each at a definite temperature.

FIG. 515.



Ellsworth, Ohio.

Physical Characters. H., 1.5 to 2. Sp. gr., 2.31 to 2.33.

LUSTRE, pearly, silky, vitreous.

STREAK, white.

COLOR, white, colorless, gray, red, yellow, brown.

TRANSPARENT to opaque.

TENACITY, brittle, laminæ flexible.

CLEAVAGE easy parallel to clino pinacoid and positive unit ortho dome. The cleavage fragments are rhombic plates with angles 66° and 114°. Other less prominent cleavages also exist.

BEFORE BLOWPIPE, ETC.—When heated quickly becomes white and opaque and fuses to an alkaline globule, coloring the flame yellowish-red. In closed tube yields water. Soluble in hydrochloric acid. The powdered dehydrated mineral when mixed with water will form a compact mass. Gives sulphur reaction.

VARIETIES.

Selenite.—Crystals or transparent cleavable masses.

Satin Spar.—Fine translucent fibrous varieties with sheen of silk.

Alabaster.—Compact and fine grained, suitable for carving.

Rock Gypsum.—Scaly, granular or dull colored and compact.

SIMILAR SPECIES.—Talc, brucite, mica, calcite, heulandite, stilbite. It is softer than all but talc, lacks the greasy feeling of talc and is further characterized by quiet solubility, cleavages and calcium flame.

REMARKS.—Gypsum occurs in large beds with limestones, marls, and clays, and in volcanic regions with sulphur. It is frequently formed by the action of the sulphuric acid from decomposing sulphides, upon calcareous minerals. It is also formed by the dehydration of anhydrite, by the evaporation of lakes and seas and by the action, in volcanic regions, of sulphurous vapors on limestone.

The largest producing locality in the United States is in the region of Alabas Michigan. Other producing localities are Ottawa county, Ohio, Smith and Wa ington counties, Virginia, Webster county, Iowa, and many places in central western New York. Deposits of gypsum in quantity are also known at Scottsb Ala., Calcasien, La., Royston's Bluff, Ark. Also in Texas, Colorado, Kansas, M tana, Utah and most of the other States and Territories. Large quantities are an ally imported from New Brunswick and Nova Scotia. Celebrated deposits also oc in Spain and Sicily.

USES.—When burned and ground it is called plaster-of-Pa In this state if mixed with water, it becomes hard and sets, is us for the production of casts, moulds, cements, washes and the ha finish on inside walls of houses.

Land plaster is ground gypsum, and is used on soils. Mi uses are: Satin spar for cheap jewelry, selenite in optical work a alabaster in carving.

APATITE.—Asparagus Stone. Phosphate Rock.

COMPOSITION.—$Ca_5(Cl.F)(PO_4)_3$.

GENERAL DESCRIPTION.—Large and small hexagonal pris usually of green or red color, but sometimes violet, white or yell Also in compact varieties which are commonly dull-gray white, rock-like masses or nodules not unlike common limesto

FIG. 516.

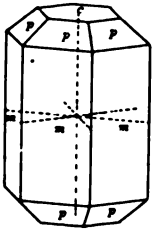


FIG. 517.

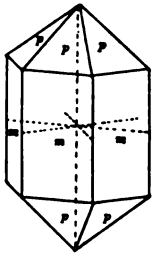


FIG. 518.

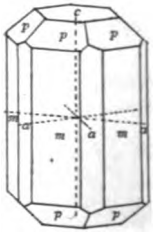


FIG. 519.

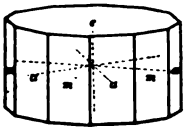
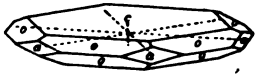
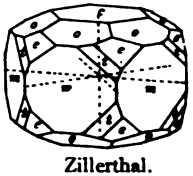


FIG. 520.



Paris, Me.

FIG. 521.



Zillerthal.

CRYSTALLIZATION.—Hexagonal. Class 3° order pyramid, p. Axis $\dot{c} = 0.735$. Usually the unit prism m terminated by the u pyramid p with or without the base c. More rarely the seco

order prism a or the low pyramid $o = a : \infty a : a : \frac{1}{2}c$ and occasionally third order pyramids as $t = \frac{1}{3}a : 4a : a : \frac{1}{3}c$, Fig. 521.

Angles are: $pp = 142° 16'$; $rr = 157° 29'$; $cp = 139° 42'$; $cr = 157° 1'$.

Optically—, with low refraction and weak double refraction.

Physical Characters. H., 4.5 to 5. Sp. gr., 3.17 to 3.23.

LUSTRE, vitreous to resinous. TRANSPARENT to opaque.

STREAK, white. TENACITY, brittle.

COLOR, green, red, brown, yellow, violet, white, colorless.

CLEAVAGE, imperfect basal and prismatic.

BEFORE BLOWPIPE, ETC.—Fuses with difficulty on sharp edges and colors the flame yellowish-red, or, if moistened with concentrated sulphuric acid, colors the flame momentarily bluish-green. Easily soluble in hydrochloric acid.

If to ammonium molybdate in nitric acid solution a few drops of a nitric acid solution of apatite be added, a bright-yellow precipitate will be thrown down on heating. In the chlorine variety silver nitrate will produce a curdy white precipitate in the nitric acid solution.

VARIETIES.—Certain mineral deposits are essentially of the same composition as crystalline apatite.

Phosphorite.—Concretionary masses, with fibrous or scaly structure. H = 4.5.

Osteolite.—Compact, earthy, impure material, of white or gray color. H., 1 to 2.

Phosphate Rock or Nodules.—The former in place of original deposition, the latter chiefly in river beds. Massive, gray, white, brown or black. H., 2 to 5.

Guano.—Granular to sponge-like and compact material, of gray to brown color. Sometimes with lamellar structure.

SIMILAR SPECIES.—Green crystals, differ from beryl in lustre, hardness and solubility. Red crystals differ from willemite in not gelatinizing or yielding zinc.

REMARKS.—Occurs in granites, limestones, tin veins, beds of iron ore, etc., frequently as inclusions in other minerals, and is of both igneous and secondary origin. The most productive American localities for the pure mineral are in Ontario and Quebec, Canada; Ottawa County, Quebec, having several productive mines. Other deposits, but smaller in extent, occur at Bolton, Mass.; Crown Point, N. Y., and Hurdstown, N. J. Immense deposits of the phosphate rock, so largely used in fer-

tilizers, occur in eastern South Carolina and in Florida; in the latter case under a wide belt of country and extending through several counties in the central p the State.

USES.—The massive varieties and some crystalline deposits nish most of the phosphates for fertilizers. It is converted soluble phosphates by treatment with sulphuric acid, in wh state it is available as plant food. Apatite is also used in manufacture of phosphorus.

PHARMACOLITE.

COMPOSITION.—$CaHAsO_4.2H_2O$, (CaO 25.9, As_2O_5 53.3, H_2O 20.8 per cent.)

GENERAL DESCRIPTION.—White or pink silky fibres or powder, and rarely monoclinic crystals.

PHYSICAL CHARACTERS.—Translucent to opaque. Lustre, silky, dull. C white or tinged red by erythrite. Streak, white. H., 2 to 2.5. Sp. gr., 2.64 to

BEFORE BLOWPIPE, ETC.—Fuses to a white or bluish enamel and colors the light blue. On charcoal, yields garlic odor. In closed tube, yields water. soluble in acids.

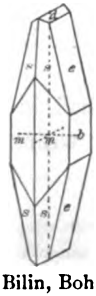
REMARKS.—Occurs with arsenical ores, especially smaltite, arsenopyrite proustite.

ARAGONITE.—Flos Ferri.

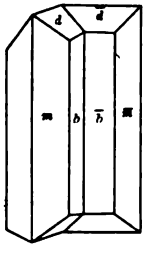
COMPOSITION.—$CaCO_3$, (CaO 56.0, CO_2 44.0 per cent.).

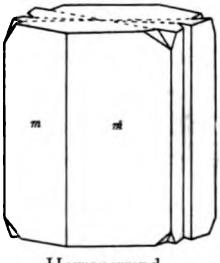
GENERAL DESCRIPTION.—This form of calcium carbonat found in orthorhombic crystals, which are frequently pseu hexagonal from twinning, and as groups of acutely termin needle crystals, which grade into fine fibres. It also occurs actitic, incrusting and in pure white groups of interlacing, c like stems. The prevailing tint is white, but is occasionally v or pale green.

FIG. 522. FIG. 523. FIG. 524. FIG. 525.



Bilin, Boh.





Herrengrund.

CRYSTALLIZATION.—Orthorhombic. Axes $\breve{a} : \bar{b} : \dot{c} = 0.622$ 0.721. Occasionally simple crystals, Fig. 522, with acute do

and pyramids such as $e = \infty \breve{a} : \bar{b} : 6c$ and $s = \frac{4}{3} \breve{a} : \bar{b} : 6c$. These grade into needle-like forms, Fig. 526. More frequently twinned, with twin plane m, giving prisms with pseudo-hexagonal cross sections, Fig. 524 and 525.

Angles are: $mm = 116° 12'$; $dd = 108° 27'$; $rv = 49° 39'$.

Optically —. Axial plane a. Acute bisectrix normal to c. Axial angle for yellow light, $2E = 30° 54'$.

FIG. 526.

Cumberland.

Physical Characters. H., 3.5 to 4. Sp. gr., 2.93 to 2.95.

LUSTRE, vitreous. TRANSLUCENT or transparent.

STREAK, white. TENACITY, brittle.

COLOR, white, violet, yellow, pale green.

CLEAVAGE.—Parallel to brachy pinacoid, prism, and brachy dome.

BEFORE BLOWPIPE, ETC.—Infusible, colors flame red. In closed tube decrepitates, loses weight and falls to pieces. With hydrochloric acid, dissolves with rapid effervescence.

SIMILAR SPECIES.—Needle crystals differ from those of natrolite in the terminations. Strontianite and witherite have higher specific gravity and are fusible. Calcite differs in form and cleaves in three directions with equal ease yielding diedral angles of 105° 5′, whereas aragonite cleaves: 1. Easily parallel to the brachy pinacoid, yielding plates. 2. Indistinctly parallel to prism, yielding angle of 116° 12′. 3. Very indistinctly parallel to a brachy dome.

REMARKS.—Aragonite is largely deposited from carbonated water solution principally in rock cavities and mineral veins. It is found with gypsum and in beds of serpentine and with iron ores as flos ferri, the coraloidal variety.

It can be changed into calcite by heat, and the difference between it and calcite is supposed to be that the calcite is deposited from cold solution and aragonite from hot solution. It is not of common occurrence, but is found at Sulphur Creek and Colton, California, also in Solano County, Cal.; in Lockport and Edenville, N. Y.; in Madison County, N. Y.; Haddam, Ct.: Warsaw, Ill., etc.

CALCITE.—Calcspar, Limestone, Marble, Iceland Spar, Etc.

COMPOSITION.—$CaCO_3$, (CaO 56.0, CO_2 44.0 per cent.).

GENERAL DESCRIPTION.—Yellowish white to white or colorless, more or less transparent crystals, usually rhombohedrons or scalenohedrons. Massive with easy cleavage or coarse to fine-

grained, stalactitic, and occasionally fibrous, lamellar or pulv
lent.

FIG. 527.

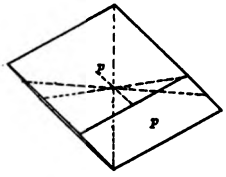


FIG. 528.

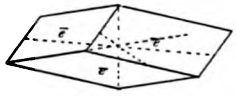


FIG. 529.

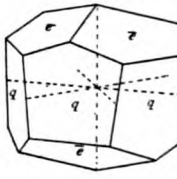


FIG. 530.

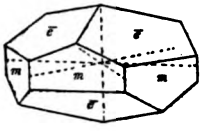


FIG. 531.

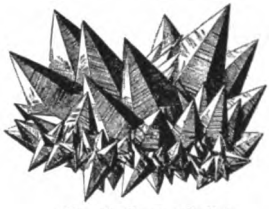
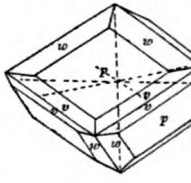


FIG. 532.



Dog Tooth Spar, Geikie.

FIG. 533.

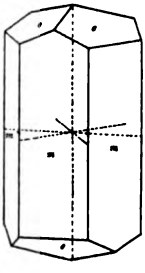


FIG. 534.

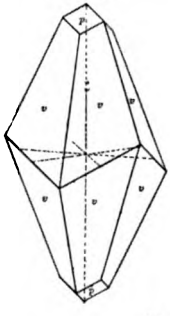


FIG. 535.

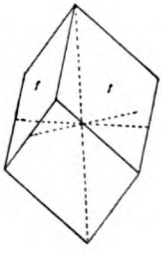


FIG. 536.

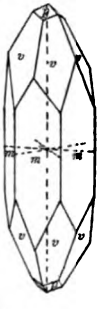


FIG. 537.

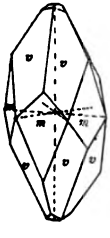


FIG. 538.

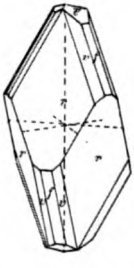
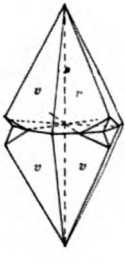


FIG. 539.



CRYSTALLIZATION.—Hexagonal. Scalenohedral class, p.
Axis $c = 0.854$.

Occurs in several hundred forms, of which the most common are the rhombohedra: p, the unit; $e = a : \infty a : a : \frac{1}{2}c$; $f = a : \infty a : a : 2c$; $q = a : \infty a : a : 16c$; the scalenohedron: $v = \frac{8}{3}a : 3a : a : 3c$, and the unit prism. Twins are frequent by several laws, see p. 68. Important angles are $pp = 105° 5'$; $ee = 134° 57'$; $ff = 78° 51'$; $qq = 60° 36'$. The polar edges vv are 104° 38′ and 144° 24′.

Optically −. With very strong double refraction, but weak refraction ($\alpha = 1.486$; $\gamma = 1.658$ for yellow light).

Physical Characters. H., 3. Sp. gr., 2.71 to 2.72.

LUSTRE, vitreous to dull. TRANSPARENT to opaque.

STREAK, white. TENACITY, brittle.

COLOR, yellow, white, colorless, or pale shades of red, green, blue, etc.

CLEAVAGE, parallel to the rhombohedron, therefore yielding dihedral angles of 105° 5′ and 74° 55′.

BEFORE BLOWPIPE, ETC.—Infusible. Becomes opaque and alkaline and colors flame red. Soluble readily in cold dilute acids, with vigorous effervescence.

VARIETIES.—The following are the most prominent varieties:

Iceland Spar.—Colorless, transparent crystals and masses.

Dog Tooth Spar.—Scalenohedral crystals, supposed to resemble canine teeth in shape.

Fontainebleau Sandstone.—Crystals containing up to 60 per cent. of sand.

Satin Spar.—Fibrous, with silky lustre.

Argentine.—Foliated, pearly masses.

Marble.—Coarse to fine granular masses, crystalline.

Limestone.—Dull, compact material, not composed of crystalline grains.

Chalk.—Soft, dull-white, earthy masses.

Calcareous Marl.—Soft, earthy and intermixed with clay.

Stalactites.—Icicle-like cylinders and cones, formed by partial evaporation of dripping water.

Stalagmite.—The material forming under the drip on the floor of the cavern.

Travertine, Onyx.—Deposits from springs or rivers, in banded layers.

Other names, such as *Hydraulic Limestone, Lithographic Lime-*

stone, *Rock Meal*, *Plumbocalcite*, *Spartaite*, etc., are of minor importance, and are chiefly based on color, use, locality, etc., and do not generally indicate important structural or chemical differences.

SIMILAR SPECIES.—The distinctions from aragonite have been given under that mineral. Dolomite differs in slow partial solution in cold dilute acids, instead of rapid and complete effervescence.

REMARKS.—Calcite is very widely distributed. It is derived, in great part, from fossil remains, shells, corals, etc, but also, in considerable part, by the decomposition of calcium silicates by hot carbonated waters, and possibly, in a degree, by the action of heat on aragonite. The carbonated waters deposit aragonite or calcite, according to the temperature of the solution. In the production of marble Vermont is far ahead of any other State, and the centre of the industry is situated at Rutland. Georgia and Tennessee also produce large quantities, especially of a beautiful, coarse, granular structure. Alabama, California, New York, Pennsylvania and Massachusetts also have large deposits, some of which are worked. Crystallized calcite occurs throughout the world in all limestone regions. In the United States these localities are innumerable and transparent varieties are common. Rossie, N. Y.; Warsaw, Ill., and Llano and Lampasas Counties, Texas, may be especially noteworthy. Fine stalactite occur in the caves of Virginia, Kentucky and New York. Deposits from thermal springs are common in the Yellowstone Park, and similar deposits occurring in San Luis Obispo County, California, are cut and polished, yielding slabs of onyx marble of extreme beauty.

USES.—Limestone and marble are important building stones and the latter is also used for statuary, ornaments, interior work, tombstones, etc. Limestone, again, is used for making quicklime and as a flux in smelting siliceous ore, in glass-making, in many chemical processes, in hydraulic cement, as a lithographic stone, etc. Iceland spar is used in optical apparatus for polarizing light.

DOLOMITE.—Pearl Spar, Magnesian Limestone.

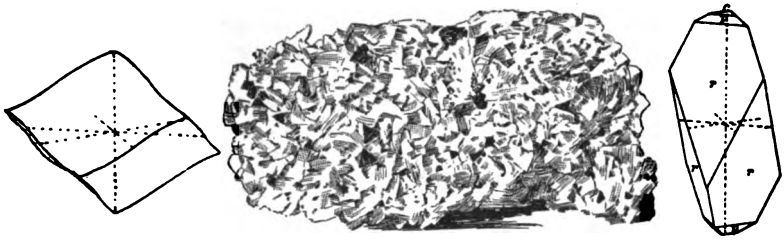
COMPOSITION.—$(Ca.Mg)CO_3$ often contains iron or manganese.

GENERAL DESCRIPTION.—Small, white, pink or yellow, rhombohedral crystals, usually with curved faces, or more frequently white, massive marble, with coarse to fine grain; or gray, white and bluish, compact limestone.

CRYSTALLIZATION.—Hexagonal, class of third order rhombohedron, p. 46. Axis $\dot{c} = 0.832$. Usually the unit rhombohedron p, Fig. 540. Sometimes the more acute rhombohedron $r = a : \infty a : a : 4c$. Important angles are $pp = 106° 15'$; $rr = 66°$, 7

Optically—, with even stronger double refraction than calcite

FIG. 540. FIG. 541. FIG. 542.



Joplin, Mo.

Physical Characters. H., 3.5 to 4. Sp. gr., 2.8 to 2.9.
LUSTRE, vitreous or pearly. TRANSLUCENT to opaque.
STREAK, white. TENACITY, brittle.
COLOR, white, pink, greenish-gray, brown or black.
CLEAVAGE. Rhombohedral. Angles, 106° 15′ and 73° 45′.

BEFORE BLOWPIPE, ETC.—Infusible, colors flame yellowish-red and becomes alkaline. With cobalt solution, becomes pink. *Fragments* are very slightly attacked by cold dilute acid. The powdered mineral is sometimes attacked vigorously by cold dilute acid, but sometimes is not. On heating there is a vigorous effervescence.

SIMILAR SPECIES.—Differs from calcite in effervescence, color with cobalt solution and frequent curvature of rhombohedral planes. It differs from siderite and ankerite in not becoming magnetic on heating.

REMARKS.—Dolomite is frequently the chief constituent of whole mountain ranges and may have formed: 1. From a solution of the mixed carbonates of calcium and magnesium in carbonated waters. 2. From calcite by infiltration of waters containing magnesium carbonate. 3. By solution of part of calcium carbonate of a magnesian limestone in preference to the less soluble magnesium carbonate, thus increasing the proportion of the latter. Many of the marbles of Vermont, Georgia and Tennessee contain magnesium, and frequently enough to be classed under dolomite. Crystals are common in many localities, especially in the zinc region of Missouri, in many places in the limestone region of Western New York, in the gorge at Niagara, at Glen Falls and Brewsters, N. Y., at Stony Point, N. C.; Roxbury, Vt., and elsewhere.

USES.—The same as for calcite. The dolomite limestone and marble are less soluble than the calcite varieties, and are to that extent, preferable for construction. It is also used for making epsom salts.

ANKERITE.

COMPOSITION.—(Ca.Mg.Fe)CO_3 sometimes containing manganese.

GENERAL DESCRIPTION.—Gray to brown rhombohedral crystals like those of sid also cleavable and granular masses and compact.

PHYSICAL CHARACTERS.—Translucent to opaque. Lustre, vitreous to pearly. C gray, yellow or brown. Streak, white or nearly so. H., 3.5 to 4. Sp. gr., 2.95 t Brittle. Cleavage, rhombohedral. $R \wedge R = 106° 12'$.

BEFORE BLOWPIPE, ETC.—Infusible, darkens and becomes magnetic. Solu acids with effervescence.

SCHEELITE.

COMPOSITION.—$CaWO_4$, (CaO 19.4, WO_3 80.6 per cent.), so times with replacement by molybdenum.

GENERAL DESCRIPTION.—Heavy brownish white or white ma and square pyramids. Also drusy crusts of yellow or br crystals.

FIG. 543.

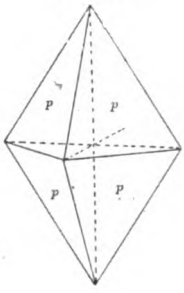
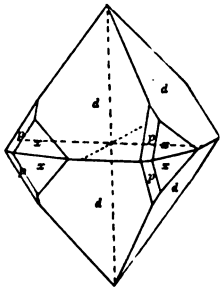
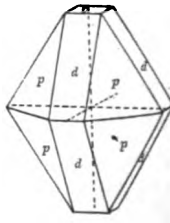


FIG. 544.



Schlackenwald.

FIG. 545.



Trumbull, Conn.

CRYSTALLIZATION.—Tetragonal. Class of third order pyra p. 29. Axis $c = 1.536$.

The unit first order pyramid p and second order d are common with sometimes a modifying third order pyramid, $a : 3a : 3c$. Angles are $pp = 100° 5'$; $ee = 107° 20'$.

Optically +.

Physical Characters. H., 4.5 to 5. Sp. gr., 5.4 to 6.1.

LUSTRE, adamantine. TRANSPARENT to opaqu

STREAK, white. TENACITY, brittle.

COLOR, pale yellow, gray, brown, white or green.

CLEAVAGE, distinct parallel to first order pyramid, indis parallel to second order pyramid.

BEFORE BLOWPIPE, ETC.—Fusible with difficulty on sharp e In salt of phosphorus forms a clear bead which in the redu

flame becomes deep blue, and if the bead is powdered and dissolved in dilute hydrochloric acid it yields a deep blue solution, especially on addition of metallic tin. Scheelite is soluble in hydrochloric or nitric acid, leaving a yellow residue.

SIMILAR SPECIES.—Distinguished among non-metallic minerals by its weight and behavior in salt of phosphorus.

REMARKS.—Scheelite occurs in crystalline rocks, and usually with cassiterite, wolframite, topaz, fluorite, molybdenite, and in quartz. It changes into wolframite, and also forms from wolframite. The mineral is by no means common, but is found at Monroe and Trumbull, Conn.; Flowe mine, S. C., in Nevada, Idaho, and Colorado. Also in large crystals at Marlow, Quebec.

USES.—Scheelite is used as a source of tungsten, which has important properties when used in the manufacture of ferro-tungsten and tungsten steel. Other applications are in the manufacture of tungstic acid, from which a yellow pigment is obtained, and tungstate of soda, which renders fabrics almost incombustible.

PEROVSKITE.

COMPOSITION.—$CaTiO_3$.

GENERAL DESCRIPTION.—Light yellow to black cubic crystals and kidney-shaped masses. Also as a rock constituent in microscopic octahedral crystals.

PHYSICAL CHARACTERS.—Color, yellow, brown and black. Lustre, adamantine. Streak, grayish. Brittle. H., 5.5. Sp. gr., 4.1. Transparent to opaque.

BEFORE BLOWPIPE, ETC.—Infusible. Gives titanium reactions in S. Ph. Decomposed by hot sulphuric acid. Insoluble in hydrochloric acid.

REMARKS.—Found in serpentine at Syracuse, N. Y., in chlorite slate at Achmatovsk Urals and in talcose schist in Zermatt, Tyrol.

THE MAGNESIUM MINERALS.

The minerals described are: *Hydroxide*, BRUCITE; *Sulphate*, EPSOMITE; *Carbonate*, MAGNESITE; *Aluminate*, SPINEL. Magnesia is also the principal base in several important silicates and occurs in many others, and in the carbonate dolomite.

The carbonate, magnesite, is not rare, over 30,000 tons being produced annually and the hydroxide and sulphate also occur in considerable quantities.

Magnesite is used as a lining for the converters in the basic processes for steel, and for other purposes where a very refractory material is desired. It is the favorite source of carbon dioxide in seltzer and soda water manufacture, as the treatment with sulphuric acid leaves a soluble residue of crude epsom salts which can be recovered. It is also used in the manufacture of certain kinds of wood-pulp paper.

The metal magnesium prepared by the electrolysis of the dc chloride of potassium and magnesium, and purified by distill out of contact with air, is now made in some quantity in the s of ribbon and as coarse grains. It is used in flash lights to duce a vivid light for photographing in absence of sunlight, reducing agent in the preparation of some of the rarer elemen a purifying agent to remove the last traces of oxygen from co nickel and steel and as a dehydrating agent for certain oils an alcohol. The metal is steadily increasing in commercial im tance.

BRUCITE.

COMPOSITION.—$Mg(OH)_2$, (MgO 69.0, H_2O 31.0 per cent.)

GENERAL DESCRIPTION.—White or gray translucent foli masses with pearly or wax-like lustre. Also fibrous and in tab hexagonal crystals.

Physical Characters. H., 2.5. Sp. gr., 2.38 to 2.4.
LUSTRE, pearly or wax-like. TRANSLUCENT.
STREAK, white. TENACITY, sectile and flexibl
COLOR, white, bluish, greenish. CLEAVAGE, basal.

BEFORE BLOWPIPE, ETC.—Infusible, becomes alkaline, and cobalt solution becomes pink. Yields water in closed tube. S ble in hydrochloric acid.

SIMILAR SPECIES.—Harder and more soluble than foliated or gypsum, and quite infusible.

REMARKS.—Brucite is usually found in serpentine or limestone with magnes hydromagnesite. On exposure it becomes coated with a white powder, and is s times changed to serpentine or hydromagnesite. Its most prominent American lo is at Texas, Pa., also at Fritz Island in the same State; at Brewsters, N. Y Hoboken, N. J.

EPSOMITE.—Epsom Salt.

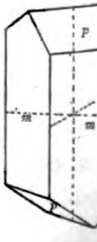
COMPOSITION.—$MgSO_4 + 7\ H_2O$, (MgO 16.3, SO_3 32.5, H_2O 51.2 per cent.)

GENERAL DESCRIPTION.—A delicate white fibrous efflorescence or earthy white crust with a characteristic bitter taste. Also common in solution in mineral water. Occasionally in needle crystals, which are especially noticeable as representing the sphenoidal class of symmetry in the orthorhombic system. Optically.—,

PHYSICAL CHARACTERS.—Transparent or translucent. Lustre, vitreous or dull. Color and streak, white. H., 2 to 2.5. Sp. gr., 1.75. Taste, bitter and salt.

BEFORE BLOWPIPE, ETC.—Fuses at first, but beomes infusible after the water of crystallization has been driven off. With co-

FIG. 54



balt solution becomes pink. In closed tube yields acid water. Easily soluble in water.

REMARKS.—Epsomite is formed by action of the suiphuric acid of decomposing sulphides, upon such magnesian minerals as serpentine and magnesite.

MAGNESITE.

COMPOSITION.—$MgCO_3$, (MgO 47.6, CO_2 52.4 per cent.), with sometimes iron or manganese replacing part of the magnesium.

GENERAL DESCRIPTION.—White chalk-like lumps and veins in serpentine. Rarely fibrous or in rhombohedral crystals closely agreeing with dolomite in form and angle. $c = 0.811$. $R \wedge R = 107° 24'$.

Physical Characters. H., 3.5 to 4.5. Sp. gr., 3 to 3.12.
LUSTRE, dull, vitreous or silky, OPAQUE to translucent.
STREAK, white. TENACITY, brittle.
COLOR, white, yellow, brown. FRACTURE, conchoidal.

BEFORE BLOWPIPE, ETC.—Infusible, becomes alkaline. With cobalt solution becomes pink. Soluble with effervescence in warm hydrochloric acid, but does not effervesce in cold dilute acid. No decided precipitate is produced by addition of sulphuric acid, whereas heavy precipitates form with solutions of calcite and dolomite.

SIMILAR SPECIES.—Differs from dolomite and calcite in not yielding the calcium flame.

REMARKS.—Usually formed with serpentine by action of carbonated waters on eruptive magnesian rocks, such as olivine (chrysolite), or when the decomposition is carried further the results are magnesite and quartz. As the former is the more common decomposition, magnesite usually occurs with serpentine and also with other magnesian minerals, such as talc, brucite, dolomite, etc.

Found at Bolton and Sutton, Province of Quebec, at Texas, Pa., Barehill, Md., and at several localities in California and Massachusetts.

USES.—It is used in the lining of converters in the basic process for steel, and for lining kilns in the manufacture of sulphuric acid and for other purposes where a non-conducting and refractory material is required. It also is used in obtaining carbon dioxide for soda water, the residue being converted into epsom salts. Epsom salts, magnesia, and magnesia alba are also made from magnesite.

SPINEL.—Balas Ruby.

COMPOSITION.—$Mg(AlO_2)_2$, (MgO 28.2, Al_2O_3 71.8 per cent.). Iron, manganese and chromium are sometimes found.

GENERAL DESCRIPTION.—Usually in octahedral crystals, sim
or twinned, which cannot be scratched by steel or quartz and v
in color according to composition. Also in rolled pebbles
loose crystals.

CRYSTALLIZATION.—Isometric, the octahedron p or this mo
fied by the dodecahedron d or the trisoctahedron $o = a : 3a :$
Index of refraction with yellow light 1.7155.

FIG. 547.

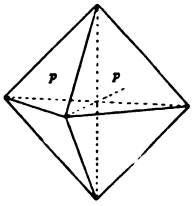


FIG. 548.

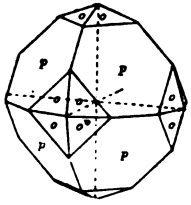
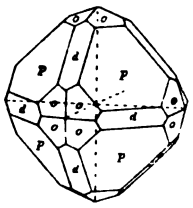


FIG. 549.



Physical Characters. H., 8. Sp. gr., 3.5 to 4.5.

LUSTRE, vitreous. TRANSPARENT to opaque

STREAK, white. TENACITY, brittle.

COLOR, red, green, blue, black, brown, yellow.

CLEAVAGE, octahedral.

BEFORE BLOWPIPE, ETC.—Infusible, often changing color,
red variety becomes green, then nearly colorless, finally red.
powder is turned blue by cobalt solution. Insoluble in hyc
chloric or nitric acid, but somewhat soluble in sulphuric acid.

VARIETIES.—

Balas Ruby or Ruby Spinel (Magnesia Spinel).—Clear red
reddish, often transparent. Sp. gr., 3.5 to 3.6.

Ceylonite (Iron Magnesia Spinel).—Dark-green, brown, bl
usually opaque.

Picotite (Chrome Spinel).—Yellowish to greenish-brown, tra
lucent.

SIMILAR SPECIES.—Characterized by octahedral crystals and
hardness.

REMARKS.—Occurs in limestone, serpentine, gneiss, etc., associated with corun
chondrodite, brucite, etc, and sometimes changed to talc, muscovite or serpen
Gem specimens have been obtained at Hamburg, N. J.; San Luis Obispo, Cal.,
Orange County, N. Y. The crystals also occur in many localities in North Caro
Massachusetts and near the New York and New Jersey line. Especially abunda
Ceylon and Burmah.

USES.—Transparent varieties are used as gems.

CHAPTER XXXIII.

ALUMINUM MINERALS.

The minerals described are: *Fluoride*, CRYOLITE; *Oxides and Hydroxides*, CORUNDUM, BAUXITE, DIASPORE, GIBBSITE; *Sulphates*, ALUNOGEN, ALUMINITE, ALUNITE. *Phosphates*, TURQUOIS, WAVELLITE, LAZULITE. ALUMINUM is also present in many silicates.

The minerals of aluminum, aside from the clays, have important commercial applications, which may be roughly classified as: I. Ores of Aluminum. II. Abrasive materials. III. Gems.

Ores of Aluminum.

Metallic aluminum, formerly prepared only by reduction of the chloride by the metal sodium, is now made in relatively large quantities by electrolysis. In 1899 there was produced in this country 3,250* tons of the metal, which sold as low as 28 cents per pound.

Only bauxite and gibbsite are at present used as ores, bauxite being preferred on account of cheapness, as gibbsite is not found in quantity, whereas about 36,000 tons of bauxite were mined in the U. S. in 1899. Corundum is too difficult to obtain and has too high a value as abrasive material, and the abundant clays and silicates contain a much smaller percentage of aluminum, and before using, need to be decomposed and freed from silica.

The ore is heated with sodium carbonate to low redness, in order to produce sodium aluminate without rendering the silica or iron soluble. On dissolving out the sodium aluminate with water and passing carbon dioxide through the solution, aluminum hydroxide is formed, which yields the oxide when heated. By this mode of procedure most of the iron and silicon is separated, which would otherwise be reduced by the current and alloyed with the aluminum.

For the production of the pure metal the oxide is decomposed by electrolysis in a fused solvent which protects the metal from

* *Engineering and Mining Journal*, 1900, p. 2.

contact with oxygen. The Hall process consists in the electro sis of the oxide in a fused bath of cryolite or the mixed fluori of sodium and aluminum. The process is carried on in iron tan the bottom and sides of which are thickly lined with carb The tanks serve as the negative electrodes and are filled with cryolite flux, to which a little fluorite is added. The positive el trodes are carbon cylinders, which dip into the electrolyte.

The cylinders are first lowered until they touch the bottom the tank, and the ground cryolite is melted as a result of the p contact. The cylinders are then raised, and the current thencefo passes through the melted liquid. The alumina is now add and is immediately dissolved by the flux and decomposed by current. The metal settles at the bottom of the bath, while oxygen combines with the carbon of the anode and escapes carbon dioxide. The metal is removed from time to time, alu ina is again added and thus the operation is continuous.

The aluminum thus produced is a white metal, with a blu tint—a good conductor of heat and electricity, malleable and d tile and not easily tarnished. It is used in the manufacture scientific apparatus where lightness, strength and non-corrosi ness are desirable, also, to a small extent, in making cook utensils; and in Germany, for making army equipments and sh for cartridges. It has a considerable use in the manufacture fancy articles and in ornamental work, and in steel, copper a zinc castings a fraction of 1 per cent. of aluminum is added to melted metal to prevent blow-holes. The powdered metal is us in the shape of a bronze powder and, in the form of aluminum and paint, it is also used for silvering letters and signs. The of aluminum in sheet form is steadily increasing and is replaci sheet copper and zinc to some extent. It is also assuming imp tance as an electrical conductor. About 500 tons were used sheet form and 650 tons for electrical conductors in 189 Aluminum is especially sonorous and is now used in the Austr army for drums, and the substitution of aluminum for brass in other band instruments is being tried.

The alloys of aluminum are extensively used especially the al with copper, known as aluminum bronze, which contains usua as much as ten per cent. of aluminum. It is extremely tough a is extensively applied in machinery, especially mine machine

* *Engineering and Mining Journal*, 1899, p. 8.

engine castings, etc. The alloys with zinc, nickel and tin are also of importance and to some extent are replacing brass.

Cryolite to the amount of about 10,000 tons per year is imported into the United States from Greenland, its only important locality, and is used in making sodium carbonate, alum and calcium fluoride. A small amount of cryolite is used as a flux in the manufacture of aluminum as above described.

Bauxite to the amount of 35,842 long tons was mined in Georgia and Alabama in 1899,* these two States having the only known American deposits of importance. This ore is the source of most of the aluminum of commerce and is also used in the production of alum and other compounds of aluminum used extensively in dyeing and calico printing. The output of the mineral is steadily increasing.

Abrasive Materials.

Corundum to the amount of about 250 tons per year is mined in the South, and a somewhat larger amount of emery is imported for use in grinding and polishing. The production of corundum is rapidly decreasing owing to the artificial production in quantity of an extremely hard carbide of silicon, known as carborundum, which is supplanting it as an abrasive.

Gems.

Rubies and sapphires, which are varieties of corundum, turquois and chrysoberyl are all found of sufficient beauty to be classed as gems or precious stones. In this country sapphires have been found in Montana, but their status in the gem market is not yet very well defined. A considerable amount of turquois of a marketable grade has been mined in New Mexico and new deposits are reported in Nevada.

CRYOLITE.—Eisstein.

COMPOSITION.—$AlNa_3F_6$. (Al 12.8, Na 32.8, F 54.4 per cent.).

GENERAL DESCRIPTION.—Soft, translucent, snow-white to colorless masses, resembling spermaceti or white wax in appearance. Occasionally with groups of triclinic crystals so slightly inclined as to closely approach cubes and cubic octahedrons in angle and form.

* *Engineering and Mining Journal*, 1900, p. 2.

Physical Characters. H., 2.5. Sp. gr., 2.95 to 3.
LUSTRE, vitreous or wax-like. TRANSLUCENT or transpar
STREAK, white. TENACITY, brittle.
COLOR.—Colorless, white, brown.
CLEAVAGE.—Basal and prismatic, angles near 90°.

BEFORE BLOWPIPE, ETC.—Fuses very easily, with strong y coloration of the flame, to a clear globule, opaque when With cobalt solution, becomes deep blue. In closed tube, acrid fumes, which attack and etch the glass. Soluble i without effervescence.

SIMILAR SPECIES.—Characterized by its easy fusibility fumes which attack glass.

REMARKS.—Found at Ivigtut, Greenland, as a large bed in a granite vein, a tains, scattered through it, crystals of siderite, quartz, chalcopyrite and galenite is the only locality where cryolite is produced in commercial quantities, but l supply seems inexhaustible. Small amounts have been found at Miask, Urals the United States at Pike's Peak, Colorado.

USES.—It is used in the manufacture of sodium carbonat aluminum hydroxide, and is made into alum. The by-produc cium fluoride, is sold to smelters and glass manufacturers. lite is also used as a flux or bath in the manufacture of alum

CORUNDUM.—Sapphire, Ruby, Emery.

COMPOSITION.—Al_2O_3, (Al 52.9, O 47.1 per cent.).

GENERAL DESCRIPTION.—With the exception of the diar the hardest of all minerals. Occurs in three great varieties, are most conveniently described separately.

Sapphire or Ruby.—Transparent to translucent, sometim crystals and of fine colors—blues, reds, greens, yellows, etc.

Adamantine Spar or Corundum.—Coarse crystals or masses nearly rectangular cleavage, or granular, slightly translucen usually in some blue, gray, brown or black color.

Emery.—Opaque, granular corundum, intimately mixed hematite or magnetite, usually dark-gray or black in color.

CRYSTALLIZATION.—Hexagonal. Scalenohedral class, p Axis $\dot{c} = 1.363$. Crystals often rough and rounded. S order pyramids predominate as n, o, and w intersecting the v axis at respectively $\frac{4}{3}c$, $\frac{4}{5}c$ and $2c$. Unit rhombohedron p a more acute form f $(2c)$ also occur. Angles $nn = 128° 2'$; $122° 22'$; $ww = 124°$.

FIG. 550.

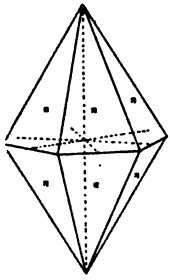


FIG. 551.

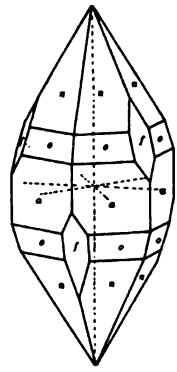
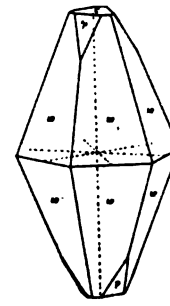


FIG. 552.



Optically—, with rather strong refraction but weak double refraction ($\alpha = 1.759$; $\gamma = 1.767$).

Physical Characters. H., 9. Sp. gr., 3.95 to 4.11.

LUSTRE, vitreous or adamantine. TRANSPARENT to opaque.

STREAK, white. TENACITY, brittle to tough.

COLOR, blue, red, green, yellow, black, brown or white.

CLEAVAGE, rhombohedral, angle of 86° 4′.

BEFORE BLOWPIPE, ETC.—Infusible and unaltered, alone or with soda, or sometimes improved in color. Becomes blue with cobalt solution at high heat. Insoluble in acids and only slowly soluble in borax or salt of phosphorus.

REMARKS.—Occurs in granular limestone, granite, gneiss and other crystalline rocks and in the gravel of river-beds. It is usually associated with chloritic minerals, rarely with quartz, and is frequently found altered, and many alteration products occur, as spinel, feldspar, mica, tourmaline, cyanite, fibrolite, etc. The American localities producing corundum or emery are: Raburn County, Ga.; Macon, Clay and Jackson Counties, N. C.; Westchester County, N. Y.; Chester County, Pa., and Chester, Mass. Fair-sized rubies and sapphires have been obtained near Helena, Montana, and at several localities in North Carolina. The finest rubies are obtained from Upper Burmah and Ceylon.

USES.—Sapphire and ruby, when clear and transparent, are valuable gems, the ruby sometimes being more highly valued than the same weight of diamond. The various colors have different names; Blue, *sapphire;* red, *ruby;* yellow, *oriental topaz;* green, *oriental emerald;* purple, *oriental amethyst.* Adamantine spar and emery are the most important abrasive materials, and thousands of tons are used in grinding and polishing. Corundum can be used in the electric smelting processes for aluminum, but its price makes this unprofitable.

BAUXITE.

COMPOSITION.—$Al_2O(OH)_4$, with usually part of the Al replaced by Fe.

GENERAL DESCRIPTION.—Disseminated, rounded grains, oolitic and sponge-like to clay-like masses. Also fine-grained, compact. Usually white, or, if ferruginous, will be yellow, brown or red.

Physical Characters. H., 1 to 3. Sp. gr., 2.4 to 2.5.
LUSTRE, dull or earthy. OPAQUE.
STREAK, like color. TENACITY, brittle.
COLOR, white, red, yellow, brown or black.

BEFORE BLOWPIPE, ETC.—Infusible. Becomes deep blue with cobalt solution, and may become magnetic in reducing flame. In closed tube yields water at high heat. Soluble with difficulty in hydrochloric acid.

REMARKS.—Bauxite may have been deposited from solution in hot alkaline waters or may have resulted from alteration of corundum. It is usually found with clay or kaolin associated with other aluminum minerals. Large deposits exists at Beaux, France, Lake Wochein, Carniola, and in Antrim, Ireland. In the United States it is mined at Linwood, Ga., and Piedmont, Ala. The production at these two places is extensive, and numerous large deposits occur throughout several counties in this region near the State boundaries. Immense amounts of the mineral are also found in Saline and Pulaski Counties, Arkansas.

USES.—Is the chief source of aluminum, and is also used in the linings of basic converters, Siemens-Martin furnaces, etc., and in the manufacture of alum.

DIASPORE.

COMPOSITION.—AlO(OH), (Al_2O_3 85.1, H_2O 14.9 per cent.).

GENERAL DESCRIPTION.—Thin, flat, orthorhombic prisms, foliated masses and thin scales. When pure, it is transparent and white or pinkish in color. When impure, it is often brown.

PHYSICAL CHARACTERS.—Transparent to nearly opaque. Lustre, pearly and vitreous. Color, gray, white, pink, yellow, brown. Streak, white. H., 6.5 to 7. Sp. gr., 3.3 to 3.5. Very brittle. Cleaves into plates.

BEFORE BLOWPIPE, ETC.—Infusible. Usually decrepitates. With cobalt solution, becomes deep blue. In closed tube, yields water at high heat. Insoluble in acids.

SIMILAR SPECIES.—Distinguished by its hardness, cleavage and decrepitation.

REMARKS.—Occurs with corundum and its associates.

GIBBSITE.

COMPOSITION.—$Al(OH)_3$, (Al_2O_3 65.4, H_2O 34.6 per cent.).

GENERAL DESCRIPTION.—A white or nearly white mineral, usu-

ally occurring in small stalactites or thin mamillary crusts, with smooth surface and sometimes fibrous internal structure. Rarely in small six-sided monoclinic crystals. When breathed upon, it has a strong clay-like odor.

Physical Characters. H., 2.5 to 3.5. Sp. Gr., 2.38.
LUSTRE, faint vitreous. TRANSLUCENT.
STREAK, white. TENACITY, brittle to tough.
COLOR, white, greenish, reddish, yellow. CLEAVAGE, basal.

BEFORE BLOWPIPE, ETC.—Infusible, exfoliates, glows and becomes white. With cobalt solution becomes deep blue. In closed tube yields water. Soluble in hydrochloric or sulphuric acid.

REMARKS.—If gibbsite could only be found in quantity it would be even more valuable than bauxite for the manufacture of aluminum. No large deposits, however, are known, and the mineral is not mined except when it occurs in comparatively small quantity with the bauxite of Georgia and Alabama. The mineral is found in even smaller quantity at Richmond and Lenox, Mass., and in Dutchess and Orange counties, N. Y. Foreign localities also are rare.

ALUNOGEN.

COMPOSITION.—$Al_2(SO_4)_3 + 18\ H_2O$, (Al_2O_3 15 3, SO_3 36.0, H_2O 48.7 per cent.).

GENERAL DESCRIPTION.—A delicate fibrous crust of white or yellow color. Sometimes massive. Tastes like alum.

PHYSICAL CHARACTERS.—Translucent. Lustre, vitreous or silky. Color, white yellowish or reddish. Streak, white. H., 1.5 to 2. Sp. gr., 1.6 to 1.8. Taste, like alum.

BEFORE BLOWPIPE, ETC.—Melts in its own water of crystallization, but becomes infusible. It is colored deep blue by cobalt solution. In closed tube yields much acid water. Easily soluble in water.

REMARKS.—Formed by action of sulphuric acid of decomposing sulphides upon aluminous shales. Also formed during volcanic action.

ALUMINITE.

COMPOSITION.—$Al_4(OH)_4SO_4$, (Al_2O_3 29.6, SO_3 23.3, H_2O 47.1 per cent.).

GENERAL DESCRIPTION.—Usually found in white rounded or irregular masses of chalk-like texture and peculiar harsh feeling.

PHYSICAL CHARACTERS.—Opaque. Lustre, dull or earthy. Color and streak, white. H., 1 to 2. Sp. gr., 1.66. Meagre to the touch and adheres to the tongue.

BEFORE BLOWPIPE, ETC.—Infusible. In closed tube yields much acid water. With cobalt solution becomes deep blue. Easily soluble in acid.

REMARKS.—Found in clay beds. Expense of transportation alone keeps aluminite from the list of aluminium ores. Quite extensive deposits occur near Silver City, New Mexico, also near Trinidad, Colo., and in others of the Western States.

ALUNITE.—Alum Stone.

COMPOSITION.—$K(AlO)_3(SO_4)_2 + 3\ H_2O$, ($Al_2O_3$ 37.0, K_2O 11.4, SO_3 38.6, H_2O 13 per cent.).

GENERAL DESCRIPTION.—Occurs fibrous and in tabular to nearly cubic rhombohedral crystals, or so intermixed with a siliceous material as to form a hard granular and nearly white rock.

Physical Characters. H., 3.5 to 4. Sp. gr., 2.58 to 2.75.
LUSTRE, vitreous. TRANSPARENT to nearly opaque.
STREAK, white. TENACITY, brittle.
COLOR, white, grayish or reddish.

BEFORE BLOWPIPE, ETC.—Infusible and decrepitates. With cobalt solution becomes deep blue. With soda infusible, but the mass will stain silver. In closed tube yields water at a red heat. Imperfectly soluble in hydrochloric or sulphuric acid.

REMARKS.—Formed by action of sulphur dioxide and steam upon trachyte or allied rocks. Occurs at Tolfa, Italy, in Hungary and in Rosita Hills, Colorado.

USES.—By roasting and lixivation with water, alum is obtained, and the Tolfa rock is so treated for manufacture of Roman alum. The rock is also used for millstones.

TURQUOIS.

COMPOSITION.—$Al_2(OH)_3PO_4 \cdot H_2O$ and always contains some copper which gives it color.

GENERAL DESCRIPTION.—Sky blue to green opaque nodules or or veins, also in rolled masses.

Physical Characters. H., 6. Sp. gr., 2.6 to 2.83.
LUSTRE, dull or wax-like. OPAQUE or slightly translucent.
STREAK, white or pale green. TENACITY, rather brittle.
COLOR, sky-blue to apple-green.

BEFORE BLOWPIPE, ETC.—Infusible, becomes brown and colors the flame green. In salt of phosphorus yields bead greenish-blue when cold, which on charcoal in the reducing flame becomes opaque red. Soluble in hydrochloric acid, the solution becoming fine blue with ammonia. In a nitric acid solution of ammonium molybdate produces a yellow precipitate on boiling.

SIMILAR SPECIES.—It is harder than chrysocolla.

REMARKS.—Turquois is mined in the United States at Los Cerrillos in New Mexico, and fine material is obtained. Also in Grant county, New Mexico. Previous to the opening of these mines turquois had been obtained almost altogether from the famous Persian locality and from Arabia. The mineral is also known to occur in Arizona, California, Colorado and Nevada.

USES.—As a gem.

WAVELLITE.

COMPOSITION.—$Al_6(OH)_6(PO_4)_4 + 9H_2O$, ($Al_2O_3$ 38.0, P_2O_5 35.2, H_2O 26.8 per cent.). F is sometimes present.

GENERAL DESCRIPTION.—Hemispherical masses which, when broken yield complete or partial circles with radiating crystals. The component crystals are rarely large enough to be measured. Occasionally stalactitic. Color most frequently white, green or yellow.

FIG. 553.

Physical Characters. H., 3.5 to 4. Sp. gr., 2.31 to 2.34.

LUSTRE, vitreous. TRANSLUCENT.

STREAK, white. TENACITY, brittle.

COLOR, colorless, white, yellow, green, brown, blue, black.

BEFORE BLOWPIPE, ETC.—Whitens, swells, and splits, but does not fuse. With cobalt solution becomes deep blue. In closed tube yields acid water. Soluble in hydrochloric acid. Ammonium molybdate produces a yellow precipitate from nitric acid solutions.

REMARKS.—In the United States is most abundant at Magnet Cove, Ark., West Whiteland, Pa., and Silver Hill, N. C. It is without industrial use.

LAZULITE.

COMPOSITION.—$(Mg.Fe.Ca)Al_2(OH)_2(PO_4)_2$.

GENERAL DESCRIPTION.—Azure blue acute monoclinic pyramids and masses. Usually quite opaque.

PHYSICAL CHARACTERS.—Opaque or nearly so. Lustre, vitreous. Color, deep sky blue. Streak, white. H., 5 to 6. Sp. gr., 3.05 to 3.12. Brittle.

BEFORE BLOWPIPE, ETC.—Infusible, but becomes white, cracks and falls to pi coloring the flame bluish-green, especially when moistened with sulphuric acid. closed tube yields water and turns white. Insoluble in acids.

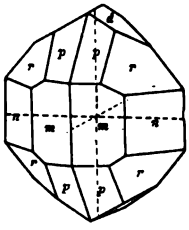
REMARKS.—Occurs in veins in clay slate, quartzite, etc.

CHRYSOBERYL.

COMPOSITION.—$GlAl_2O_4$, (GlO 19.8, Al_2O_3 80.2 per cent.).

GENERAL DESCRIPTION.—Pale green or yellowish tabular cr tals; thicker deep emerald-green crystals, which by transmit light are a purplish red; and rolled pebbles like green bottle gl but often with an internal opalescence. Very hard.

FIG. 554.



Urals.

FIG. 555.

Haddam, Conn.

CRYSTALLIZATION.—Orthorhombic $\breve{a} : \bar{b} : \dot{c} = 0.470 : 1 : 0.5$ Often flat plates or flat contact twins with feather-like striatio Fig. 555. Alexandrite occurs in simple, Fig. 554, or twinned cr tals showing unit pyramid p and prism m with brachy pyrami $= 2\breve{a} : \bar{b} : 2c$ and prism $n = 2\breve{a} : \bar{b} : \infty c$. Angles are mm 129° 39′; $nn = 93°\ 32'$; $pp = 139°\ 53'$; $rr = 107°\ 43'$.

Optically +. Axial plane the brachy pinacoid. Acute bis trix vertical. Pleochroic.

Physical Characters. H., 8.5. Sp. gr., 3.5 to 3.84.

LUSTRE, vitreous to greasy. TRANSLUCENT to transparent

STREAK, white. TENACITY, brittle.

COLOR, pale yellowish green to emerald green.

BEFORE BLOWPIPE, ETC.—Infusible. In powder, is turned b by cobalt solution. Insoluble in acids.

VARIETIES.—*Alexandrite*, the deep emerald-green variety, wh is columbine red by transmitted light.

Cymophane or Cats Eye.—Yellowish-green and opalescent.

REMARKS.—No fine gems have been found in the United States, although the eral occurs sparingly in Stowe, Peru and Canton, Me., Greenfield, N. Y., Hadd Conn. The best gems are obtained from Ceylon, the Ural Mountains and Brazil.

USES.— As a gem, especially the alexandrite and cat's eye.

CHAPTER XXXIV.

BORON, SULPHUR, TELLURIUM, HYDROGEN AND CARBON MINERALS.

THE BORON MINERALS.

The minerals described are: *Boric Acid*, SASSOLITE; *Borates*, BORAX, ULEXITE, COLEMANITE (Priceite and Pandermite), BORACITE (Stassfurtite). Boron is also a constituent of some common silicates, *e. g.*, tourmaline and datolite.

Commercial borax is manufactured from all the minerals mentioned, and has important uses, based either on its power to unite with almost any oxide to form a fusible compound, or upon its antiseptic or detergent properties. It is used in welding, as basis of enamels on metal or porcelain, as a flux, as an antiseptic in packing meat, in antiseptic powders and soaps, and in washing, dyeing, and tanning.

Sassolite to the extent of about 2500 tons yearly, is obtained by condensing and evaporating the steam issuing from fumaroles in the mountains of Tuscany. About 1200 tons of pandermite are annually obtained in Asia Minor. Boracite is from the mines at Stassfurt, Germany. In this country the borax minerals are obtained from the "marshes" of the Great Basin, especially those in Nevada and California. In San Bernardino County, Cal., calcium borates are mined from a vein. In 1897 about 10,000 tons of borax were extracted in California and Nevada.*

When the crude material is borax with other sodium and calcium salts, the borax is extracted by boiling in hot water, cooling and crystallizing. The calcium borates are decomposed by sodium carbonate or sulphate to form borax, or by sulphuric or hydrochloric acid if boracic acid is first to be produced.

SASSOLITE.—Natural Boracic Acid.

COMPOSITION.—H_3BO_3, (B_2O_3 56.4, H_2O 43.6 per cent.).

GENERAL DESCRIPTION.—Small white or yellowish scales, of

**Mineral Industry*, 1898, p. 63.

pearly lustre, acid taste, and somewhat unctuous feel. stalactitic or in minute monoclinic crystals. Chiefly oc solution or vapor in volcanic regions.

Physical Characters. H., 1. Sp. gr., 1.43.

LUSTRE, pearly.	TRANSLUCENT.
STREAK, white.	TENACITY, britt
COLOR, white or yellowish.	TASTE, sour or

BEFORE BLOWPIPE, ETC.—Fuses easily with intumesce clear glass without color, but colors the flame yellowish-gr closed tube, yields water. Soluble in water.

REMARKS.—In the region of volcanoes sassolite is brought to the surface of steam, collects in the water from these jets, and, to some extent, forms a more or less solid. The only productive locality is in Tuscany. It also for proportion of the boron compounds at the California borax localities.

USES.—It is an important source of borax.

BORAX.—Tinkal.

COMPOSITION.—$Na_2B_4O_7.10H_2O$, (B_2O_3 36.6, Na_2O 16. 47.2 per cent.).

GENERAL DESCRIPTION.—A glistening, white or near efflorescence or constituent of certain soils, but more fr in solution in lakes, or as well-formed monoclinic crystal mud of these lakes. The crystals closely resemble thos roxene in form and angle.

Physical Characters. H., 2 to 2.5. Sp. gr., 1.69 to 1.

LUSTRE, vitreous to dull.	TRANSLUCENT to op
STREAK, white.	TENACITY, brittle.
COLOR, white, gray, bluish, greenish.	TASTE, alkaline.

BEFORE BLOWPIPE, ETC.—Swells greatly and fuses to glass. Colors flame yellow, and if mixed to a paste wit of acid potassium sulphate and powdered fluorite, and fuse color the flame bright green. In closed tube, swells, b yields much water and a burnt odor. Soluble in water. I with a few drops of sulphuric acid, covered with alcohol, alcohol set on fire, a green flame is obtained.

REMARKS.—Borax in the United States is produced from the deposits both Nevada and California. The Nevada localities are mainly in Esmeral while those of California are in Lake, Bernardino and Inyo Counties.

Uses.—In welding, soldering, soap-making, glass-making, glazing, as a flux in assaying, refining and testing metals, as a preservative, in medicine, and as chief ingredient of many washing powders and antiseptic preparations.

ULEXITE.—Boronatrocalcite.

COMPOSITION.—$CaNaB_5O_9.8H_2O$, (B_2O_3 43.0, CaO 13.8, Na_2O 7.7, H_2O 35.5 per cent.).

GENERAL DESCRIPTION.—White, rounded masses (cotton-balls) of loosely-compacted, intertwined, silky fibres, which are easily pulverized between the fingers.

Physical Characters. H., 1. Sp. gr., 1.65.

LUSTRE, silky. TRANSLUCENT.

COLOR and STREAK, white. TENACITY, brittle.

BEFORE BLOWPIPE, ETC.—Fuses very easily, with intumescence to a clear glass. Colors flame intense yellow, and will yield green flame, as with borax. In closed tube yields water. Soluble in acids.

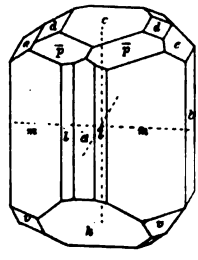
REMARKS.—Occurs in dry lakes or on the banks surrounding partially dried lakes, with halite, gypsum, glauberite, borax, etc. Is probably formed by the action of soluble calcium salts on boracic acid and borax in solution in the same waters. It is abundant in Esmeralda County, Nevada, and is also found in several of the California borax localities and in the gypsum beds of Nova Scotia. Large deposits also occur in the dry plains at the north of Chili.

USES.—It is a source of part of the borax of commerce.

COLEMANITE.—Priceite Pandermite.

COMPOSITION.—$Ca_2B_6O_{11} + 5H_2O$, (B_2O_3 50.9, CaO 27.2, H_2O 21.9 per cent.).

FIG. 556.



GENERAL DESCRIPTION.—Occurs in groups of colorless transparent crystals resembling those of datolite but usually larger, and in simpler wedge-shaped forms, also in compact white masses like porcelain and in loosely aggregated chalk-like masses.

CRYSTALLIZATION.—Monoclinic. Axes $\dot{a} : \bar{b} : \dot{c} = 0.775 : 1 : 0.541$; $\beta = 69° 51'$. Common faces

are: $l = 2a : b : \infty c$; $v = a : b : 2c$; $e = \infty a : b : 2c$; $h = a : \infty b : 2c$. Usually short prismatic and highly modified. Angles, $mm = 107° 56'$; $mc = 106° 11'$; $ac = 110° 9'$.

Physical Characters. H., 4 to 4.5. Sp. gr., 2.26 to 2.48.

LUSTRE, vitreous to dull. TRANSPARENT to opaque.
STREAK, white. TENACITY, brittle.
COLOR, white or colorless.

Before Blowpipe, Etc.—Fuses easily, coloring flame green. Insoluble in water, easily soluble in hot hydrochloric acid with separation of boric acid on cooling.

Varieties.

PRICEITE.—Loosely compacted white chalky masses.

PANDERMITE.—Firm compact porcelain-like white masses.

REMARKS.—Priceite occurs in Curry County, Oregon, in layers between slate and steatite. Pandermite is found in a bed beneath gypsum near Panderma on the Sea of Marmora. Colemanite at Inyo and San Bernardino Counties, Cal., with celestite and quartz. Especially abundant near Daggett in the Mojave Desert.

USES.—Is an important source of borax and yields a large part of the American output.

BORACITE.—Stassfurtite.

COMPOSITION.—$Mg_7Cl_2B_{16}O_{30}$ (B_2O_3 62.57, MgO 31.28, Cl 7.93 per cent.).

GENERAL DESCRIPTION.—Snow-white, rather soft masses (stassfurtite) and small *hard* glassy isometric crystals of the Hextetrahedral class, p. 18, usually showing the tetrahedron p with or without the cube a and dodecahedron d. Strongly pyroelectric.

FIG. 557.

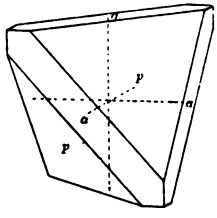
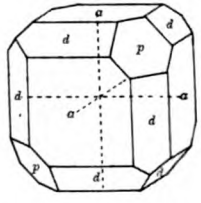


FIG. 558.



PHYSICAL CHARACTERS—Transparent to opaque. Lustre, vitreous. Color, white, yellowish, greenish. Streak, white. H., 7 (crystals), 4.5 (masses). Sp. gr., 2.9 to 3. Brittle.

BEFORE BLOWPIPE, ETC.—Fuses easily with intumescence, to a white glass and colors the flame yellowish green. In closed tube yields no water or but little. Soluble slowly in hydrochloric acid.

REMARKS.—Occurs in deposits of halite, gypsum, anhydrite, and especially in the immense beds of potassium and magnesium salts at Stassfurt, Prussia.

THE SULPHUR AND TELLURIUM MINERALS.

The minerals described are: SULPHUR and TELLURIUM; the principal sulphur minerals, however, are the sulphides and sulphates elsewhere described.

According to the estimate of W. H. Adams,* the United States consumed a total of 316,303 long tons of sulphur in 1897. Of this amount 137,725 tons was in the form of brimstone, almost wholly imported from Sicily, and 178,578 tons was present in pyrite from which it was burned. About two-thirds of the pyrite was imported and mainly from the Rio Tinto mines of Spain. Sulphur is also recovered in large quantities from the former waste products of gas works, Leblanc soda factories and other chemical works. Considerable quantities are also burned off from the sulphides of zinc and copper during the recovery of the metals and in a few localities, notably in Germany, the sulphur dioxide fumes are utilized in the manufacture of sulphuric acid.

Nine-tenths of the world's supply of native sulphur is obtained from the Island of Sicily. In this country 1,337 long tons were produced in 1899.†

Sulphur is extracted from the native mineral by simple fusion and consequent separation from the gangue. The common method in use in Sicily involves the burning of part of the sulphur to melt the remainder, causing heavy loss of the element. The crude sulphur may be refined by sublimation. Pyrite is burned directly in specially constructed furnaces, the sulphur dioxide produced being used almost solely in the manufacture of sulphuric acid.

TELLURIUM is included in this section on account of its close chemical relation to sulphur. It has no commercial importance.

SULPHUR.—Brimstone.

COMPOSITION.—S, sometimes with traces of tellurium, selenium, or arsenic. Often mixed with clay or bitumen.

GENERAL DESCRIPTION.—Yellow, resinous, orthorhombic pyramids, usually translucent or transparent; also in crusts, stalactites, spherical shapes, and powder. Color usually pale-yellow to sulphur-yellow, but is sometimes brown or green.

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* *Mineral Industry*, 1898, p. 562.

† *Engineering and Mining Journal*, 1900, p. 2.

Fig. 559.

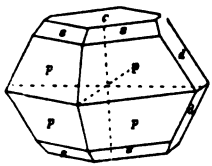
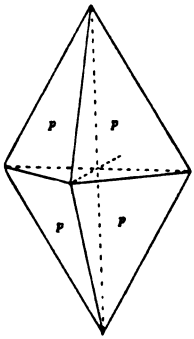


Fig. 560.



CRYSTALLIZATION.—Orthorhombic. Axes $\breve{a} : \bar{b} : c = 0.81$ 1.903. Usually the pyramid p, sometimes modified by the b the pyramid $s = \breve{a} : b : \frac{1}{3} c$, or the dome $d = \infty \breve{a} : b : c$. A $pp = 106° 26'$; $ss = 126° 51'$; $cd = 117° 43'$.

Optically +. Axial plane, the brachy pinacoid. Acute bis vertical. Axial angle with yellow light $2V = 69° 5'$.

Physical Characters. H., 1.5 to 2.5. Sp. gr., 2.05 to 2.

LUSTRE, resinous. TRANSPARENT to transl

STREAK, white or pale yellow. TENACITY, brittle.

COLOR, yellow, yellowish-orange, brown or gray.

CLEAVAGE, parallel to base, prism and pyramid, not perfec

BEFORE BLOWPIPE, ETC.—Melts easily, then takes fire and with a blue flame and suffocating odor of sulphur dioxide closed tube melts and yields a fusible sublimate, brown hot, y cold, and if rubbed on a moistened silver coin the coin is black Insoluble in acids.

REMARKS.—Formed in large deposits by the decomposition of sulphides, or phates, especially gypsum, which by water and decaying organic matter are red the sulphide with subsequent production of hydrogen sulphide which on decomp forms sulphur. Sulphur is also deposited from hot springs.

The great sulphur producing region of the world is the island of Sicily. D are numerous in the United States, and have been developed at Cove Creek and Utah; and Winnemucca, Nevada. Extensive deposits are also known in Cal Louisiana, Wyoming and Texas. Less important occurrences are numerous.

USES.—Sulphur is used in immense quantities for the manuf of sulphuric acid, gunpowder, matches, rubber goods blea medicines, etc. Large quantities of it, however, are recove various chemical and metallurgical operations as by-products

TELLURIUM.

COMPOSITION.—Te with a little Se, S, Au, Ag, etc.

GENERAL DESCRIPTION.—A soft tin white mineral of metallic lustre occurring fine grained or in minute hexagonal prisms.

PHYSICAL CHARACTERS.—Opaque. Lustre, metallic. Color and streak, tin-white. H., 2 to 2.5. Sp. gr., 6.1 to 6.3. Rather brittle.

BEFORE BLOWPIPE, ETC.—On charcoal fuses easily, volatilizes, coloring flame green and forming a white coat, which is made rose color by transferring to porcelain and moistening with sulphuric acid. Soluble in hydrochloric acid.

THE HYDROGEN MINERALS.

HYDROGEN is a constituent of many minerals being present in combination and as water of crystallization. It is present to a limited extent in natural gas and in volcanic gases, it escapes in combination with sulphur from many sulphur springs and in combination with carbon occurs as marsh gas, petroleum, ozocerite, etc. It has been of the utmost importance in mineral formation and alteration and for that reason is considered here. Its compound WATER is properly included as a mineral.

WATER.—Ice, Snow.

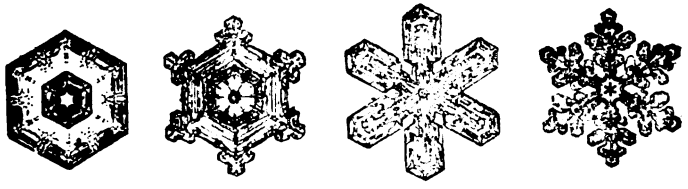
COMPOSITION.—H_2O (H., 11.1, O., 88.9 per cent.).

GENERAL DESCRIPTION.—*Ice or snow* at or below 0° C. *Water* from 0° to 100° C. *Steam* above 100° C., or aqueous vapor at all ordinary temperatures.

CRYSTALLIZATION.—Hexagonal. Axis $\dot{c} = 1.403$ approximately.

As snow, the crystals are principally compound star-like forms branching at 60° and of great diversity. Simple crystals are sometimes found as hail. Optically +.

FIG. 561. FIG. 562. FIG. 563. FIG. 564.



Magnified Snow Crystals.

Physical Characters. H. (ice), 1.5. Sp. gr. (ice), 0.91.

LUSTRE, vitreous. TRANSPARENT.

STREAK, colorless. TENACITY, brittle.

COLOR, white or colorless, pale blue in thick layers.

Tasteless if pure.

BEFORE BLOWPIPE, ETC.—Melts at 0° C. Under pressure of 760 mm. boils at 100° C. and is converted into steam.

REMARKS.—Rarely pure, usually containing air, carbon dioxide, some of the salts of calcium, magnesium, sodium, potassium, etc., and even traces of the metals. When pure it is tasteless and a universal solvent.

THE CARBON MINERALS.

The definite minerals described are: DIAMOND and GRAPHITE. In addition to these COAL, ASPHALTUM, PETROLEUM, OZOCERITE and AMBER are economically important carbon compounds which are on the border line of mineralogy, being without definite composition or crystalline form.

Carbon also exists in all organic matter, in all carbonates; in the carbon dioxide of the air; and in natural gas.

DIAMONDS have been found in this country, but practically, the production for the world is from the South African mines, with a limited amount from New South Wales and from Brazil. Nearly three million carats were mined in Kimberley, South Africa, in 1897.*

GRAPHITE is mined in New York, Pennsylvania, and Rhode Island and to a limited extent in a few other States. In 1898 the output of the mines in this country was 1900 tons.† The total product of the world is over 50,000 tons annually, obtained mainly from Austria and Ceylon. The uses of graphite are numerous, the best known being, pencils, crucibles, stove polish, lubricants, paints for iron and foundry facings.

Mineral coal, excluding peat and lignite which retain the woody structure, is compact massive material produced by a gradual alteration of organic deposits chiefly vegetable. Bituminous, or soft coal, which retains a large amount of volatile matter readily converted by heat into gases was mined to the extent of 158,955,931 tons in this country in 1898.‡ Anthracite, or hard coal, which contains little volatile matter was produced during the same year§ to the amount of 49,947,571 tons. About one-half of our total output of coal is mined in Pennsylvania. The United States now produces about one-third of the coal of the world.

**Mineral Industry*, 1898.

†*Engineering and Mining Journal*, 1899, p. 3.

‡*Engineering and Mining Journal*, 1899, p. 3.

§*Ibid.*

ASPHALTUM or mineral pitch is a mixture of different hydrocarbons, brown to black in color and grading between liquid and solid. Different names, such as elaterite, gilsonite, and albertite, have been given to varieties from different localities.

The chief locality for asphaltum is the famous pitch lake of the island of Trinidad, although deposits of asphaltic sandstone are mined in California, Utah, Kentucky, and other States in this country, and asphaltic limestones are mined in France and Switzerland. Nearly 200,000 tons were used in the United States in 1897, of which about two-thirds were imported.

The principal use is for street pavements, usually mixed with 70 to 80 per cent. of sharp sand, 5 to 15 per cent. of limestone, and a little coal-tar residium. It is also used as cement, roofing, and floor material, and for coating wood or metal to prevent decay or rust.

Asphaltum is also a constituent of some varnishes.

PETROLEUM is closely related to asphaltum, and may be regarded as including the liquid members of the series. In 1897 the wells of this country yielded 56,985,643 barrels * of the crude oil, which was converted into naphtha, illuminating oils, lubricating oils and paraffine. It is obtained also in Canada, Russia, India and Burma.

OZOCERITE or mineral wax is essentially a paraffin, colorless to white when pure, but oftener greenish or brown, and possessing all the properties of beeswax except its stickiness. It is found in Galicia, Hungary, and Utah, and is extensively used. In the crude state it serves as an insulator for electric wires. By distilling it yields a refined product, ceresine, used for candles, waxed paper and hydrofluoric acid bottles; burning oils; paraffine; a product with properties and appearance of vaseline; and a black residiuum which in combination with india rubber constitutes the insulating material called okonite.

In 1897 over 7000 tons were mined in Hungary.

AMBER or succinite is a fossil resin found chiefly along the Prussian coast of the Baltic Sea. It is usually transparent and of a yellowish or brownish color. Its chief use is for jewelry and for mouth pieces for pipes.

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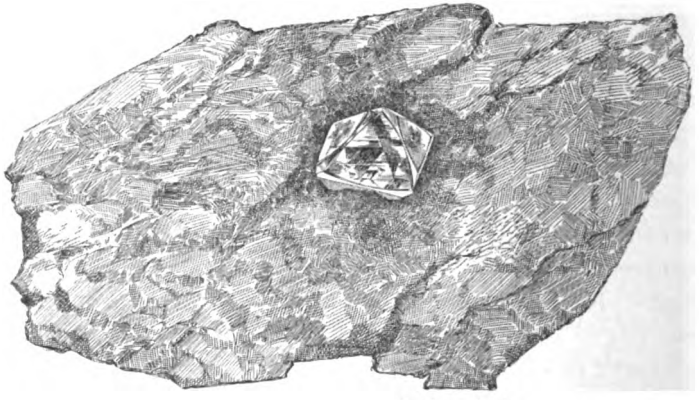
* *Mineral Industries*, 1898.

DIAMOND.

COMPOSITION.—C.

GENERAL DESCRIPTION.—Transparent, rounded, isometric crystals with a peculiar adamantine lustre like oiled glass. Usually colorless or yellow, and with easy octahedral cleavage. Also translucent, rough, rounded crystalline aggregates and opaque crystalline or compact masses of gray to black color and no distinct cleavage. Especially characterized by a hardness exceeding that of any other known substance.

FIG. 565.



De Beer's Mine, Kimberley, S. A.

CRYSTALLIZATION.—Isometric. Hextetrahedral class, p. 18. Octahedra, often showing inverted triangular depressions, see Fig. 565, and hextetrahedral modifying faces. are most common while rounded hexoctahedra and more rarely cubes and other forms occur. Frequently twinned parallel to the octahedron. Index of refraction for yellow light 2.4195.

Physical Characters. H., 10. Sp. gr., 3.15 to 3.52.

LUSTRE, adamantine. TRANSPARENT to opaque.

STREAK, colorless. TENACITY, brittle.

COLOR, colorless, yellow, rose, green, blue, gray, black.

CLEAVAGE, octahedral.

BEFORE BLOWPIPE, ETC.—Is slowly consumed, producing its equivalent of carbon dioxide. In powder it is burned by ordinary blowpipe flame. Insoluble in acids.

VARIETIES.—*Carbonado or Black Diamond.*—Opaque, dark-colored, and without cleavage. Sp. gr., 3.15 to 3.29.

Bort.—Translucent, non-cleavable, crystalline aggregates, often harder than the crystals and more tough. Sp. gr., 3.499 to 3.503. The name bort is also applied to fragments of crystals.

REMARKS.—Origin not known. The diamond is found in alluvial deposits with other minerals, such as gold, platinum, zircon. The great South African localities, however, while in part alluvial or "river diggings," are chiefly confined to a limited area where they occur enclosed in a wall of carbonaceous shale surrounding a serpentine shale core, in which are found not only the diamonds, but garnets, zircon magnetite, etc. Diamonds have also been found in quartzose conglomerates and with the so-called flexible sandstone "itacolumite."

Although diamonds have been found in isolated localities in the southern and western States no deposits, not even of an alluvial character, have been discovered in North America. By far the largest diamond deposit ever found occurs at Kimberley, South Africa, and immense quantities are mined here annually. Alluvial deposits which have become famous occur in Brazil, India, the Urals and Borneo.

USES.—As a gem when transparent and without flaw; colorless stones and those of decided tints ranking superior to yellow or brownish stones. Smaller stones, especially the translucent and opaque crystals, are used in cutting machinery, diamond drills, saws, etc., on account of their great abrasive power. The dust is also used in polishing other diamonds.

GRAPHITE.—Plumbago, Black Lead.

COMPOSITION.—C. Sometimes with iron, sand, clay, etc.

GENERAL DESCRIPTION.—Disseminated flakes or scaly to compact masses, and more rarely six-sided plates. Soft, greasy and cold to the touch; black to very dark gray in color and usually metallic in lustre. When impure it is apt to be slaty or earthy.

Physical Characters. H., 1 to 2. Sp. gr., 2.09 to 2.25.

LUSTRE, metallic to dull.	OPAQUE.
STREAK, dark-gray.	TENACITY, scales flexible, slightly sectile.
COLOR, black or dark gray.	
CLEAVAGE, basal, cleaves into plates.	UNCTUOUS, marks paper.

BEFORE BLOWPIPE, ETC.—Infusible, but is gradually burned. May react, if impure, for water, iron and sulphur. Insoluble in acids. If a piece of graphite is brought into contact with a piece of zinc in a solution of copper sulphate, it is quickly copper-plated. Molybdenite under the same test is very slowly plated.

SIMILAR SPECIES.—Differs from molybdenite in darker color, streak, flame test and salt of phosphorus bead, and as above mentioned. Micaceous hematite is harder and has a red streak.

REMARKS.—Graphite probably results from alteration of embedded organic matter coal, peat, etc., by heat, destructive distillation and pressure. It occurs disseminated in crystalline limestones and granites and in larger irregular masses. Large deposits exist in Ceylon, Austria and Eastern Siberia. Almost all the American output is obtained at Ticonderoga, N. Y. Deposits at Southampton, Pa., and near Raleigh, N. C., have also produced graphite in commercial quantities.

USES.—Graphite is used for refractory vessels, as crucibles, retorts, stove polish, etc., for lead pencils, in electroplating, in electrical supplies, in casting moulds, as a finish, as a lubricant for machinery, as a paint for iron, etc., for coating metals, shot, gunpowder, etc.

CHAPTER XXXV.

SILICA AND THE SILICATES.

THE minerals composed of silica alone and the silicates cannot conveniently be classified upon an economic basis, and we have, therefore, followed practically the order of Dana's "System of Mineralogy," Sixth Edition, believing that—in this country, at least—most collections of minerals will be arranged in this order for many years. The order herein followed is:

A.—SILICA.

B.—ANHYDROUS SILICATES:

I. Disilicates and Polysilicates.
II. Metasilicates.
III. Orthosilicates.
IV. Subsilicates.

C.—HYDROUS SILICATES:

I. Zeolite Division.
II. Mica Division.
III. Serpentine and Talc Division.
IV. Kaolin Division.

D.—TITANO SILICATES.

ECONOMIC DISCUSSION.

Aside from the occasional occurrence of certain silicates in specimens suitable for gems, only a few of this greatest group of common minerals are of economic importance as distinct minerals. The great stone or quarry industry,* however, which represents in the United States a capital of nearly $100,000,000, and produced in 1889 material worth in the rough over $50,000,000, consists in the extraction of blocks of either carbonate of lime or magnesia or of silica and silicates. For instance, in 1889 the values of materials quarried in this country were:

* The facts and figures, where given for the year 1889, are essentially those of the *Eleventh Census Report on Mineral Industries*, pp. 595 to 666. The figures for 1897 are taken from *Mineral Industry*, 1898.

Granite,	$14,464,0
Sandstone,	10,816,0
Bluestone,	1,689,6
Slate,	3,482,5

The amount of stone used in building in this country i was approximately of the value of $30,000,000.

GRANITE, commercially speaking, includes a number o durable rocks, such as granite proper, syenite, gneiss, basa rite, and andesite, which are composed of silicates—usuall or more—and principally quartz, the feldspars and the pyroxene and amphibole. It is used in enormous quan buildings, in paving blocks and in construction of brid dams, In 1889, 62,287,156 cubic feet were quarried in the States, of which 26,000,000 were used in building and 20,0 in paving blocks.

SANDSTONE is composed of grains, chiefly quartz, with so a little feldspar, mica or other minerals, and classified as s ferruginous, calcareous or argillaceous, according to the n the cement which binds the grains together. Its uses are t as those of granite, but a larger proportion of the quantit ried is used in building. In 1889, 71,571,054 cubic fe quarried in the United States.

BLUESTONE is a very hard, durable, fine-grained sandst mented together with siliceous material. It is used princi flag and curb stone. In 1889, 5,126,340 cubic feet were in the United States.

SLATE is used chiefly as roofing material and for interio such as blackboards, table tops, sinks, etc. Slate and slat factures to the amount of $3,243,220 were produced in the States in 1897.

FIBROUS TALC and compact talc, or soapstone, are ext used, the former for grinding to "mineral pulp," used i manufacture, the latter for many purposes, usually becau refractory, expands and contracts very little, retains heat w is not attacked by acids. These properties make it valu furnaces, crucibles, sinks, baths, hearths, electrical switch and cooking utensils. Talc is also used in cosmetics, re paints, slate pencils, crayons, gas tips, as a lubricant and making.

In 1897 there were produced in this country 58,836 fibrous talc and 18,974 tons of soapstone.

THE MICAS, muscovite, phlogopite and biotite, have become of great importance as non-conductors in electrical apparatus, and are also used in stove and furnace doors. The larger sheets are cut and split to the desired size; the waste is, to some extent, built up into plates suitable for certain grades of electrical work, and for covering steam boilers and pipes. Large amounts of former waste material are now ground and used for decorative interior work, to ornament porcelain and glassware, to spangle wall paper, in calico printing, as a lubricant and more recently as an absorbent of nitro glycerine and in the manufacture of certain smokeless powders. Sheet mica to the amount of 92,335 pounds was produced in this country in 1897 and 2,692 tons of scrap mica were ground.

ASBESTUS.—The minerals amphibole and serpentine, in their fibrous varieties, are known commercially as asbestos, and are extensively used as incombustible paper, cloth, cement, boiler and steam-pipe covering, yarn or rope for packing valves. Only 900 tons were obtained in 1898 in the United States. The large supply coming from Canada and Italy is the fibrous serpentine, chrysotile.

SERPENTINE is, to some extent, mined and used as an ornamental stone, but is commercially classed with the marbles.

FELDSPAR is crushed in large quantities for admixture with kaolin in the manufacture of porcelain. In the United States 20,900 tons were produced in 1898.

QUARTZ is also used in large amounts in the manufacture of sand-paper, porcelain, glass, in honestones, oilstones, and as a flux. Its colored and chalcedonic varieties are used as precious or ornamental stones. In 1897 the United States produced 750,000 long tons of quartz and quartz sand.

INFUSORIAL EARTH is calcined and made into water filters, polishing powders, soap filling and boiler and steam-pipe covering.

KAOLINITE AND CLAY.—Enormous and varied industries use as their raw material the beds of clay which result from the decomposition of the feldspars and other silicates. These beds are composed in part of some hydrous aluminum silicate such as kaolinite, but usually with intermixed quartz, mica, undecomposed feldspar, oxides and sulphides of iron. Their properties and uses depend chiefly upon their composition. Clay products to the amount of $56,121,101 were manufactured in 1897 in the United States.

The industries include the manufacture of common brick, brick, fire-brick, and hydraulic cement, all varieties of earthe stoneware and porcelain, terra cotta, sewer pipes and drai and are carried on all over the country and the world.

FULLERS EARTH, a special form of clay, was mined in Flo the extent of 17,049 tons in 1897. It is used largely in the ing and clarifying of oils.

The minerals beryl, garnet, topaz, tourmaline, spodu titanite and chrysolite are sometimes found in specimens wh valuable as gems.

SILICA.

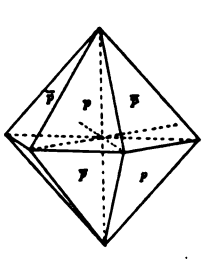
The minerals composed of silica (SiO_2) are QUARTZ, TRI and OPAL.

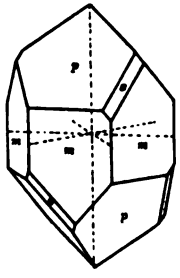
QUARTZ.—Agate, Jasper, Chalcedony.

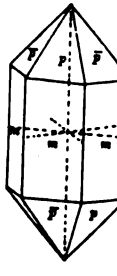
COMPOSITION.—SiO^2, (Si 46.7, O 53.3 per cent.).

GENERAL DESCRIPTION.—A hard, brittle mineral which m cur as more or less transparent, vitreous masses or as hex crystals, and of all colors, but especially colorless, milky, amethyst, smoky and red. Also found in cavities, particul translucent, non-crystalline layers of gray, yellowish and tints and with usually a mammillary, stalactitic or nodular ure. Also found as more or less opaque, non-crystallized m

FIG. 566. FIG. 567. FIG. 568.







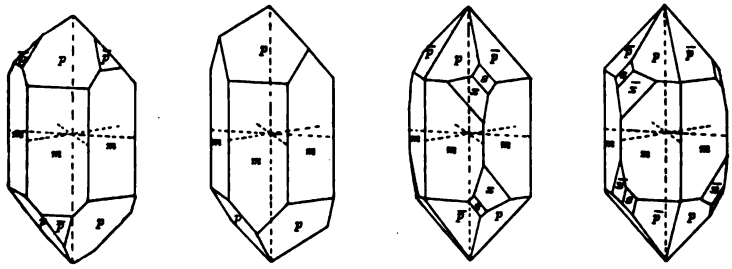
containing considerable amounts of iron, and alumina, and highly colored, as red, brown, or yellow.

In rocks quartz rarely has definite shape, but apparently last and fills the interstices between the other minerals.

CRYSTALLIZATION.—Hexagonal. Class of trigonal trap dron, p. 44. Axis $c = 1.0999$. Usually a combination o

prism m with one or both rhombohedra, p and $\bar{p}$, the former generally larger and brighter, and the prism faces nearly always horizontally striated. The second order pyramid $s = 2a : 2a : a : 2c$

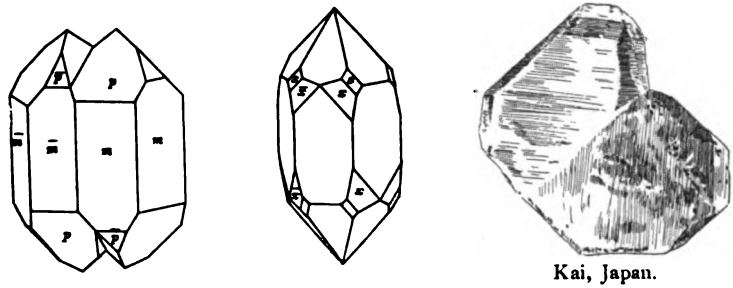
FIG. 569. FIG. 570. FIG. 571. FIG. 572.



frequently occurs and rarely the trapezohedral faces $x = \frac{6}{5}a : 6a : a : 6c$ either right, Fig. 571, or left, Fig. 572.

Angles $pp = 94° 14'$; $mp = 141° 47'$; $ms = 142° 2'$; $mx = 167° 59'$.

FIG. 573. FIG. 574. FIG. 575.



Kai, Japan.

Twinned crystals are not rare. Fig. 573 shows two crystals with twinning plane the second order prism. Fig. 574, is an intergrowth of a right-handed, Fig. 571, and a left-handed crystal, Fig. 572. Fig. 575 shows twin plane $a : 2a : 2a : c$, in which the vertical axes cross almost at right angles.

Optically +. With low refraction and weak double refraction ($\alpha = 1.544$; $\gamma = 1.553$ for yellow light). Circularly polarizing. Basal sections 1 mm. thickness turning plane of polarization for yellow light 21.7° to right or left.

Physical Characters. H., 7. Sp. Gr., 2.6 to 2.66.

LUSTRE, vitreous to greasy. TRANSPARENT to opaq

STREAK, white. TENACITY, brittle to to

COLOR, colorless and all colors.

CLEAVAGE, difficult, parallel to rhombohedron.

BEFORE BLOWPIPE, ETC.—Infusible. With soda, fuse marked effervescence to a clear or opaque bead, according proportions used. Insoluble in salt of phosphorus and soluble in borax. Insoluble in all acids except hydrofluor

VARIETIES.

A. CRYSTALLINE VARIETIES.—Vitreous in lustre, often t rent; occurring in isolated or grouped crystals or drusy s or crystalline.

Rock Crystal.—Pure, colorless or nearly colorless quartz

Amethyst.—Purple to violet and shading to white. F shows lines like those of the palm of the hand. Color dis on heating, and is probably due to a little manganese.

Rose Quartz.—Light-pink or rose-red, becoming paler exposure to light. Usually massive. Colored by titan manganese.

Yellow Quartz or *False Topaz.*—Light yellow.

Smoky Quartz.—Dark yellow to black. Smoky tint, some carbon compound.

Milky Quartz or *Greasy Quartz.*—Translucent. Usuall ive. Common as a rock constituent.

Ferruginous Quartz.—Opaque, brown or red crystals, son small and cemented like a sandstone.

Aventurine.—Spangled with scales of mica, hematite, or g

Cat's Eye.—Opalescent, grayish-brown or green quartz cluded parallel fibres of asbestus.

B. CHALCEDONIC VARIETIES.—With lustre like wax. T cent. Not in crystals. Frequently nodular, mammillary titic or filling cavities.

Chalcedony.—Pale blue or gray varieties, uniform in tint

Agate.—Strata or bands representing successive periods sition, and frequently of different tints or with irregularly colors or visible colored inclusions constituting such sub- as *banded agate, clouded agate, moss agate, ruin or fortificatio etc.*

Carnelian or Sard.—Blood-red or brownish-red.

Onyx and Sardonyx.—Parallel layers of lighter and darker color, as white and black, white and red, etc. The layers are in planes.

Chrysoprase.—Apple-green.

Prase.—Dull leek-green.

Plasma, Heliotrope and Bloodstone. Bright to dark-green, spotted with white or red dots.

C. JASPER VARIETIES.—Opaque, dull in lustre, usually high in color, impure from clay and iron.

FIG. 576.

Hot Springs, Ark.

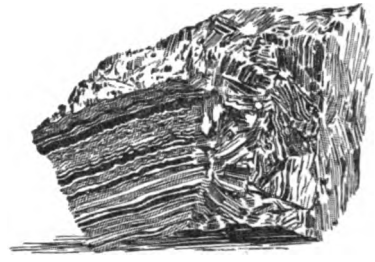
FIG. 577.

Herkimer, Co., N. Y.

FIG. 578.

Chalcedony, Antwerp, N. Y.

FIG. 579.



Agate. Schlottwitz, Saxony.

D. IN ADDITION TO THESE, there are

Flint.—Smoky-gray to nearly black, translucent nodules, found in chalk-beds.

Touchstone.—Velvet-black and opaque, on which metal streaks are easily made and compared.

Sandstones.—Quartz grains cemented by silica, iron oxide, clay, calcium carbonate, etc.

Quartzite, compact quartz, granular or slaty in structure.

REMARKS.—Quartz is chiefly found as an original constituent of such r granite, gneiss, etc, formed by igneous or plutonic action, and also, to a ve extent, as a deposit from solution in water. Silicates are attacked by car waters, forming carbonates of calcium, magnesium, sodium, etc., and leaving due of silica. This, in turn, is soluble in hot solutions of these same carbona is dissolved, transported, and, by evaporation and cooling, is redeposited, fillin cavities, veins, etc. Quartz is the most common of all solid minerals, and occ almost all other species and in almost all localities.

USES.—Aside from the uses of the quartz rocks in building large quantities of quartz are used in the manufacture of paper, glass, porcelain and as an acid flux in smelting. The cedonic varieties—agate, onyx, etc.—are often polished and as ornaments, and so also are some of the jaspers. Rock c is used in cheap jewelry, and is cut for spectacles and for forms of optical apparatus. The colored crystalline varieti often cut in cheap jewelry, and the amethyst, when of a part dark purple, is highly valued as a gem.

TRIDYMITE.

COMPOSITION.—SiO_2.

GENERAL DESCRIPTION.—Small colorless, six sided plates. Often in wedge groups of three (trillings), which are sometimes octahedral in appearance.

PHYSICAL CHARACTERS.—Transparent. Lustre, vitreous. Color, colo white. Streak, white. H., 7. Sp. gr., 2.28 to 2.33. Brittle.

BEFORE BLOWPIPE, ETC.—Like quartz, but soluble in boiling sodium carbo

REMARKS.—Occurs in cavities in volcanic rocks, such as trachyte or andesy

OPAL.

COMPOSITION.—$SiO_2.nH_2O$, (H_2O, 5 to 12 per cent.).

GENERAL DESCRIPTION.—Transparent to translucent vein masses, usually of milky-white or red color and frequently ing blue, green, red, etc., internal reflections (opalescence). grades into less translucent and opaque masses, with no pl color and somewhat resembling chalcedony, but without the like lustre. Other varieties are transparent, like melted glas opaque and earthy.

Physical Characters. H., 5.5 to 6.5. Sp. gr., 2.1 to 2.

LUSTRE, vitreous, pearly, dull. TRANSPARENT to opac

STREAK, white. TENACITY, brittle.

Color, colorless and all colors.

BEFORE BLOWPIPE, ETC.—Infusible. Becomes opaque and more or less water. Soluble in hydrofluoric acid more easil quartz and soluble in caustic alkalies.

VARIETIES.

Precious Opal.—Milky-blue, yellow or white translucent material with fine internal reflections, attributed to thin curved lamellæ, which have been cracked, bent and broken during solidification.

Fire Opal.—Reddish or brown in color and with reflections having the appearance of fire.

Common or Semi-Opal.—Translucent to opaque, with greasy lustre and of all colors, but without opalescence. Most frequently yellow or brown.

Wood Opal.—Petrified wood, the petrifying material being opal.

Opal Jasper.—Like ordinary jasper, but with resinous lustre.

Hyalite.—Colorless transparent masses resembling drops of melted glass or of gum arabic.

Geyserite, Siliceous Sinter.—Loose, porous rock of opal silica deposited from hot water. Opaque, brittle and often in stalactitic or other imitative shapes.

Fiorite or Pearl Sinter.—Pearly, translucent material found in volcanic tufa and near hot springs.

Tripolite or Infusorial Earth.—Massive, chalk-like or clay-like material composed of the remains of diatoms.

SIMILAR SPECIES.—Softer than quartz and soluble in caustic alkalies. May also yield noticeable water in a closed tube. Rarely confused with any other mineral.

REMARKS.—Occurs in fissures in igneous rocks or imbedded in limestone, clay-beds, etc. Fine precious opals are found at Gem City, Washington; at Opaline, Idaho; also in Latah County, Idaho, and Morrow County, Washington. Queretaro and Zimapan, Mexico, also yield good gems. Other famous localities are Czerwenitza, Hungary; Bula Creek, Queensland, and Wilcannia, New South Wales. Deposits of infusorial earth occur at Dunkirk, Md.; Richmond, Va.; Virginia City, Mo., also in Connecticut, New Hampshire, New Jersey and California. All of these deposits have been worked, but not continuously.

USES.—Precious and fire opals are beautiful gems. Opalized wood is cut and polished for ornament. Tripolite has many uses; *e.g.*, polishing and washing powders, lagging for boilers, cement, soluble glass, and as the dope in dynamite.

POLYSILICATES.

The POLYSILICATES may be derivatives of $H_2Si_2O_5$, $H_6Si_2O_7$, $H_4Si_3O_8$, and possibly other more complicated silicic acids, or they may be formed by isomorphic mixtures of salts of these

acids with each other or with the orthosilicates or metasili
Many of the polysilicates are so variable and so complex t
is impossible to express their composition by formula, and
others are designated by formulæ which are, at the best, bu
proximations. Under this head comes Petalite, a derivati
$H_2Si_2O_5$, and the important subdivision of the FELDSPARS, d
tives of $H_4Si_3O_8$ and of fairly definite composition.

PETALITE.

COMPOSITION.—$LiAl(Si_2O_5)_2$.

GENERAL DESCRIPTION.—Glassy white or gray foliated and cleavable mas
rarely minute, colorless crystals, like pyroxene in form.

PHYSICAL CHARACTERS.—Transparent to translucent. Lustre, vitreous.
colorless, white, gray, occasionally pink. Streak, white. H., 6 to 6.5. Sp. g
to 2.46.

BEFORE BLOWPIPE, ETC.—Phosphoresces with gentle heat; with stron
whitens and fuses on the edges and colors the flame carmine. Insoluble in ac

THE FELDSPARS.

These are of great importance as rock-forming mineral
have a close resemblance in many characters; *e.g.*:

Very similar in crystalline form. System either monocli
triclinic. Prism angles nearly 120°; many of the other
closely agreeing.

Two prominent cleavages inclined at or near 90°.

Hardness, 6 to 6.5.

Specific gravity, generally between 2.55 and 2.75.

Composition, $R'AlSi_3O_8$ or $R''Al_2Si_2O_8$, or isomorphic mi
of these.

The feldspars here described are ORTHOCLASE, MICRO
ALBITE, OLIGOCLASE, LABRADORITE, ANORTHITE.

ORTHOCLASE.—Feldspar, Potash Feldspar.

COMPOSITION.—$KAlSi_3O_8$, with some replacement by Na.

GENERAL DESCRIPTION.—Cleavable masses, showing angle
and monoclinic crystals, of flesh-red, yellow or white color.
compact, non-cleavable masses, resembling jasper or flint. S
times colorless grains or crystals.

CRYSTALLIZATION.—Monoclinic. Axes $\beta = 63° 57'$; $\dot{a}$
$= 0.659 : 1 : 0.555$. Most frequent forms: unit prism m,
coids b and c and positive orthodomes $o = \dot{a} : \infty \bar{b} : c$ and y
$\infty \bar{b} : 2c$. Angles are: $mm = 118° 47'$; $cm = 112° 13'$; $co =$
$43\frac{1}{2}'$; $cy = 99° 42'$.

Twin forms of Carlsbad type Fig. 584 (twinning plane the ortho pinacoid) very common; the Baveno type Fig. 585 (twinning plane a clino dome) and Mannebacher type (twininng plane the base *c*), Fig. 586, less common.

FIG. 580. FIG. 581. FIG. 582. FIG. 583.

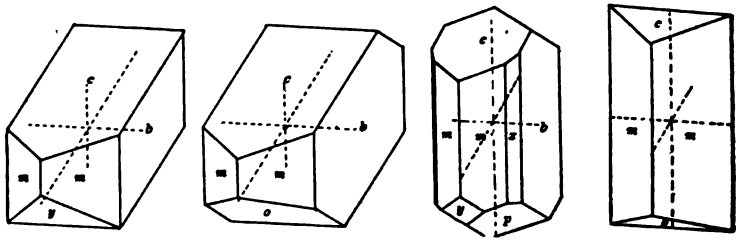
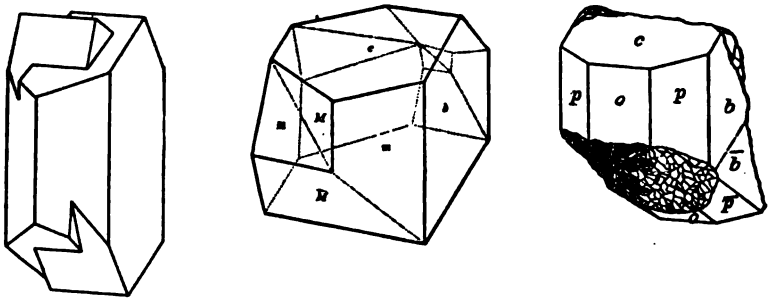


FIG. 584. FIG. 585. FIG. 586.



Optically —, with weak refraction and double refraction. Axial plane usually normal to *b*. In thin sections rarely shows multiple twinning and is frequently turbid from kaolin.

Physical Characters. H., 6 to 6.5. Sp. gr. 2.44 to 2.62.

LUSTRE, vitreous or pearly. TRANSPARENT to opaque.

STREAK, white TENACITY, brittle.

COLOR, flesh-red, yellowish, white, colorless, gray, green.

CLEAVAGE, parallel to *c* and *b*, hence at right angles.

BEFORE BLOWPIPE, ETC.—Fuses in thin splinters to a semi-transparent glass and colors flame violet. Insoluble in acids.

VARIETIES.

Ordinary.—Simple or twinned crystals of nearly opaque pale red, pale yellow, white or green color. More frequently cleavable massive as in granitic rocks.

Adularia.—Colorless to white, transparent, often opales
Usually in crystals.

Sanidine and Rhyacolite.—Glassy, white or colorless crystal
lava, trachyte, etc.

Loxoclase.—Grayish-white or yellowish crystals, which ha
tendency to cleave parallel to the ortho pinacoid.

Felsite.—Jaspery or flint-like masses of red or brown color

SIMILAR SPECIES.—Differs from the other feldspars in the cl
age at 90°, the greater difficulty of fusion, the absence of s
tions, etc.

REMARKS.—Usually of igneous origin, sometimes secondary. With mica
quartz it forms the important rocks granite, gneiss, and mica schist, and is al
basis of syenite, trachyte, porphyry, etc. It changes to kaolin quartz, opal, epidot
muscovite, by the removal of bases through the action of acid waters. Orthocl
quarried at South Glastonbury and Middletown, Conn.; Edgecomb and Brun
Me.; Chester, Mass.; Brandywine Summit, Pa.; Tarrytown and Fort Ann, N.

USES.—It is one of the constituents of porcelain and china
chiefly to form the glaze, but partly mixed with the kaolin
quartz in the body of the ware.

MICROCLINE.

COMPOSITION.—$KAlSi_3O_8$.

GENERAL DESCRIPTION.—Like orthoclase, except that the macro axis is
30′ to the vertical instead of 90°, and the basal cleavage often shows fine stri
In thin basal sections between crossed nicols it shows a peculiar interlaced structu
to two series of twin lamellae which cross nearly at right angles as in Fig. 587.

FIG. 587.

Optically —. Axial plane nearly normal to the
pinacoid.

PHYSICAL CHARACTERS.—Essentially as in orth
Sp. gr. 2.54 to 2.57, and cleavage at 89° 30′ instead

BEFORE BLOWPIPE, ETC.—As for orthoclase.

REMARKS.—Includes varieties, Amazon stone, pe
chesterlite, etc., formerly grouped under orthoclase.
interlaminated wi'h albite or orthoclase.

Anorthoclase. A triclinic sodium-potassium feldspar found mainly in the la
Pantellaria. Color, lustre and hardness the same as for other feldspars. Cl
close to 90°. Sp. gr., 2.59. Distinguished by its optical characters.

ALBITE.—Soda Feldspar, Pericline.

COMPOSITION.—$NaAlSi_3O_8$.

GENERAL DESCRIPTION.—Pure white, granular, masses
straight or curved laminæ. Less frequently in white or colo
triclinic crystals, usually small.

CRYSTALLIZATION.—Triclinic. Angles $\alpha = 94° 3'$; $\beta = 116° 29'$; $\gamma = 88° 9'$. Axes $\breve{a} : \bar{b} : \dot{c} = 0.633 : 1 : 0.558$. Simple forms, Fig. 588, usually show both hemi prisms *m* and *M*, base *c*, brachy pinacoid *b* and other modifying planes. Angles $mM = 120° 46'$; $cm = 114° 43'$; $cM = 110° 50'$; $bm = 119° 34'$.

FIG. 588.

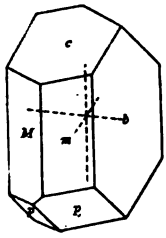


FIG. 589.

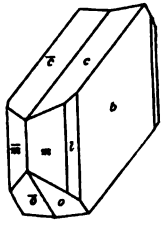
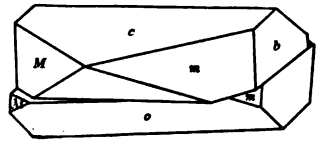


FIG. 590.



Twinning by albite law (twinning plane *b*), Fig. 589, if repeated, results in striations on *c*, while by pericline law (twinning axis, the macro axis), Fig. 590, the striations are on *b*.

Optically +, with weak refraction and double refraction. Thin sections with polarized light show parallel bands due to the twin lamellæ, and characteristic extinction angles.

Physical Characters. H., 6 to 6.5. Sp. gr., 2.62 to 2.65.

LUSTRE, vitreous. TRANSPARENT to opaque.

STREAK, white. TENACITY, brittle.

COLOR, pure white, colorless, or tinted blue, gray, red, green.

CLEAVAGE at angle of 86° 24'.

BEFORE BLOWPIPE, ETC.—Fuses in small pieces to a white enamel and colors the flame deep yellow. Insoluble in acids.

SIMILAR SPECIES.—Differs from other feldspars in whiteness, granular, and lamellar structure and strong yellow flame.

REMARKS.—Frequently found in cavities and seams in granitic and schistose rocks, especially those high in silica, often enclosing the rarer minerals, tourmaline, beryl, chrysoberyl, topaz, etc. Is chief constituent of diorite. Not easily altered.

OLIGOCLASE.—Soda Lime Feldspar.

COMPOSITION.—$n(NaAlSi_3O_8) + CaAl_2Si_2O_8$. $n = 2$ to 6.

GENERAL DESCRIPTION.—Cleavable masses, usually with fine striations on the basal cleavage surface. Color greenish-white, also in reddish or grayish masses, sometimes with fire-like reflections (sunstone). Less frequently in triclinic crystals.

Physical Characters. H., 6 to 7. Sp. gr., 2.65 to 2.67.
LUSTRE, vitreous or pearly. TRANSPARENT to op
STREAK, white. TENACITY, brittle.
COLOR, greenish, white, gray, reddish, yellowish.
CLEAVAGE, at angle of 86° 32′.

BEFORE BLOWPIPE, ETC.—Fuses rather easily to a c enamel-like glass. Insoluble in acids.

REMARKS.—Of igneous origin, occurring with orthoclase and albite in the granite type and in lavas, trachyte, serpentine, etc. It alters to epidote, etc. Good crystals are found at Fine and McComb, St. Lawrence County, N

LABRADORITE.—Lime Soda Feldspar.

COMPOSITION.—$NaAlSi_3O_8 + n(CaAl_2Si_2O_8)$. $n = 1, 2,$

GENERAL DESCRIPTION.—Dark gray cleavable masses frequently show beautiful changing colors, blue, gold, Less frequently in small triclinic crystals or colorless and or granular to flint-like.

Physical Characters. H., 5 to 6. Sp. gr., 2.7 to 2.72
LUSTRE, vitreous or pearly. TRANSLUCENT to op
STREAK, white. TENACITY, brittle.
COLOR, dark gray, greenish, brown, colorless, white.
CLEAVAGE, at angle of 86° 4′.

BEFORE BLOWPIPE, ETC.—Fuses rather easily to colorles Partially soluble in hydrochloric acid.

REMARKS.—Labradorite is of igneous origin, usually accompanied by amphibole, menaccanite or magnetite, forming the gabbros, dolerytes, and ot rocks; but is notably absent in localities containing orthoclase and quartz. readily to zeolites, calcite, datolite, etc. Found abundantly in the Adirondac in the Wichita Mountains, Ark., in Quebec and in Labrador.

USES.—It is polished for ornaments, table tops, inlaid wo

ANORTHITE.—Indianite, Lime Feldspar.

COMPOSITION.—$CaAl_2Si_2O_8$.

GENERAL DESCRIPTION.—White or red granular masses (ite), small to rather large, glassy, colorless, white, or r yellowish triclinic crystals and gray or pink cleavable mas

Physical Characters. H., 6 to 6.5. Sp. gr., 2.74 to 2.76.
LUSTRE, vitreous. TRANSPARENT to opaque.
STREAK, white. TENACITY, brittle.
COLOR, white, colorless, gray, yellow, red.
CLEAVAGE, at 85° 50′.

BEFORE BLOWPIPE, ETC.—Fuses with difficulty to a colorless glass. In fine powder, is decomposed by hydrochloric acid, sometimes with gelatinization. The solution will yield a copious white precipitate on addition of sulphuric acid.

REMARKS.—Frequently of volcanic origin, often enclosing grains of chrysolite.

THE METASILICATES.

The METASILICATES are derivatives of H_2SiO_3, and are described in the following order:

LEUCITE.

Pyroxene Group.—ENSTATITE, HYPERSTHENE, PYROXENE, SPODUMINE, WOLLASTONITE, PECTOLITE, RHODONITE.

AMPHIBOLE.

BERYL.

CYANITE.

IOLITE is an intermediate species between metasilicates and orthosilicates.

Many of the hydrous silicates are also derivatives of metasilicic acid.

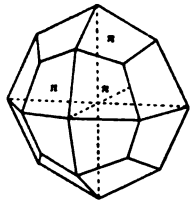
LEUCITE.

COMPOSITION.—$KAl(SiO_3)_2$.

GENERAL DESCRIPTION.—Gray, translucent to white and opaque, disseminated grains and trapezohedral crystals in volcanic rock.

CRYSTALLIZATION.—Isometric externally, but with polarized light, showing double refraction at all temperatures below 500° C.

FIG. 591.



Physical Characters. H., 5.5 to 6. Sp. gr., 2.45 to 2.50.
LUSTRE, vitreous to greasy, TRANSLUCENT to opaque.
STREAK, white. TENACITY, brittle.
COLOR, white or gray, or with yellowish or red tint.

BEFORE BLOWPIPE, ETC. Infusible. With cobalt solution, becomes blue. Soluble in hydrochloric acid, leaving a fine powder of silica.

REMARKS.—A constituent of lavas, sometimes the chief constituent. By alt changes to kaolin, mica, nephelite, orthoclase, quartz, etc. It is not com America, but is found in the Leucite Hills, Wyoming, and also in the north part of the same State. Very common in the Vesuvian lavas.

USES.—Leucite rock has long been used for millstones.

ENSTATITE.—Bronzite.

COMPOSITION.—(Mg.Fe) SiO_3.

GENERAL DESCRIPTION.—Brown to gray or green, lamellar or fibrous mass sometimes a peculiar metalloidal lustre (bronzite). Rarely in columnar ortho crystals.

PHYSICAL CHARACTERS.—Translucent to opaque. Lustre, pearly, silky o loidal. Color, brown, green, gray, yellow. Streak, white. H., 5.5. Sp. gr., 3. Brittle.

BEFORE BLOWPIPE, ETC.—Fusible on the edges. Almost insoluble in acids cobalt solution is turned pink.

REMARKS.—It is rare in quartzose rocks, but occurs frequently in meteor with chrysolitic, basaltic and granular eruptive rocks. Occurs also associat chondrodite, apatite, talc, etc. By alteration it forms serpentine, talc, and lim

HYPERSTHENE.

COMPOSITION.—(Mg.Fe)SiO_3, with more iron than enstatite.

GENERAL DESCRIPTION.—Dark-green to black, foliated masses or rare ortl bic crystals, which grade into enstatite. Frequently shows a peculiar iridesce to minute interspersed crystals.

PHYSICAL CHARACTERS.—Translucent to opaque. Lustre, pearly or met Color, dark-green to black. Streak, gray. H., 5 to 6. Sp. gr., 3.4 to 3.5.

BEFORE BLOWPIPE, ETC.—Fuses on coal to a black, magnetic mass. I soluble in hydrochloric acid.

REMARKS.—Hypersthene is common in certain granular eruptive rocks, norites, etc

In thin sections hypersthene is often strongly pleochroic while enstatite weakly so. Hypersthene often also includes tabular brown scales.

BASTITE.—An alteration product of enstatite near serpentine in composition usually foliated and of a yellowish or greenish color and has a peculiar bro lustre on the cleavage surface. H., 3.5–4. Sp. gr., 2.5–2.7.

PYROXENE.—Augite.

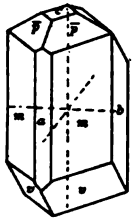
COMPOSITION.—$RSiO_3$. R = Ca, Mg, Mn, Fe, Al, chiefly

GENERAL DESCRIPTION.—Monoclinic crystals. Usually and thick, with square or nearly square cross-section, or octa and with well-developed terminal planes. Granular, foliate columnar masses and *rarely* fibrous. Color, white, various s of green, rarely bright green, and black.

CRYSTALLIZATION.—Monoclinic. $\beta = 74° 10'$. Axes $\dot{a}$ = 1.092 : 1 : 0.589.

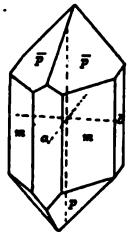
Common forms: unit prism *m*, the pinacoids *a*, *b* and *c*, the negative and, more rarely, the positive unit pyramids $\bar{p}$ and *p*, the

FIG. 592.



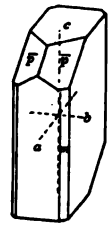
Diopside,
Pitcairn, N. Y.

FIG. 593.



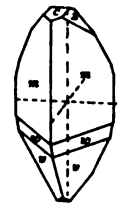
Rossie, N. Y.

FIG. 594.



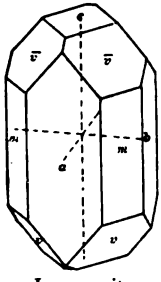
Diopside.
De Kalb, N. Y.

FIG. 595.



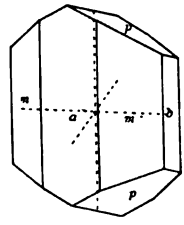
Fassaite.

FIG. 596.



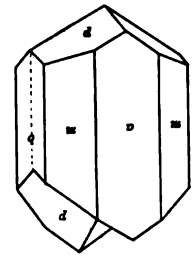
Leucaugite,
Sing Sing, N.Y.

FIG. 597.



Augite.

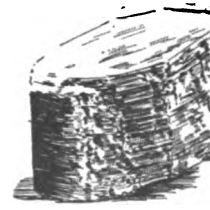
FIG. 598.



Augite twin.

negative and positive pyramids $\bar{v}$ and $v = \dot{a} : \bar{b} : 2c$. Angles are: $mm = 87° 10'$; $\bar{p}\bar{p} = 131° 31'$; $pp = 120° 49'$; $\bar{v}\bar{v} = 111° 18'$; $vv = 95° 48'$; $c\bar{p} = 146° 11'$; $c\bar{v} = 137° 58'$; $c\bar{v} = 130° 6'$; $cv = 114° 39'$.

FIG. 599.



Russell, N. Y.

Contact twins, twinning plane *a*, Fig. 598, are common. Also twin lamellæ parallel *c*, shown by striations on the vertical faces and by basal parting, Fig. 599. Optically +. Axial plane *b*. Strong double refraction. Varying axial angle. Usually not strongly pleochroic.

Physical Characters. H., 5.6. Sp. gr., 3.2 to 3.6.

LUSTRE, vitreous, dull or resinous. OPAQUE to transparent.
STREAK, white to greenish. TENACITY, brittle.
COLOR, white, green, black, brown.
CLEAVAGE, prismatic (angle 87° 10').

BEFORE BLOWPIPE, ETC.—Variable. Usually fuses ea
dark glass, sometimes to magnetic globule. Not generall
ble in acids.

VARIETIES.

Malacolite or Diopside.—$CaMg(SiO_3)_2$. Usually white o
green.

Hedenbergite.—$(Ca.Fe)(SiO_3)_2$. Grayish-green.

Augite.—Chiefly $CaMg(SiO_3)_2$, but containing also Al a
Dark-green to black, and many others which grade into eac
imperceptibly.

Diallage.—Thin foliated pyroxene, green or brown in co

SIMILAR SPECIES.—Differs from amphibole, as therein des

REMARKS.—Next to the feldspars, pyroxene is the most common const
igneous rocks. It occurs also in crystalline limestones and dolomites, and u
some light-green or white color (diopside). In serpentine it is apt to be
diallage. In granite it is usually green, and in eruptive rocks is dark-green
augite. It alters to chlorite, serpentine, amphibole, etc.

ACMITE, Ægirite.

COMPOSITION.—$NaFe(SiO_3)_2$.

GENERAL DESCRIPTION.—Occurs in long, prismatic crystals of dark gree
brown color. In acmite these are acutely terminated and in ægirite, bluntl
found needle-like and fibrous.

OPTICALLY —. Axial plane the plane of symmetry. Acute bisectrix near
to the base. Strongly pleochroic. Small extinction angle in sections parall
plane of symmetry.

PHYSICAL CHARACTERS.—Translucent. Lustre, vitreous. Color, green
brown, sometimes green on interior and brown on exterior of crystal. Streak, y
H., 6–6.5. Sp. gr., 3.5.

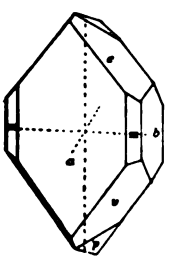
BEFORE BLOWPIPE, ETC.—Fuses easily to a black, slightly magnetic glo
colors the flame yellow. Only slightly affected by acids.

SPODUMENE.

COMPOSITION.—$LiAl(SiO_3)_2$, with some sodium replacing l

GENERAL DESCRIPTION.—White, greenish-white and *rar*
erald-green, monoclinic crystals, someti
enormous size. Also in masses. Cha
ized by breaking in broad, smooth pla
addition to regular prismatic cleavage.

FIG. 600.



CRYSTALLIZATION.— Monoclinic. Axe
$: \dot{c} = 1.124 : 1 : 0.636$; $\beta = 69° 40'$. Co
forms: the pinacoids a and b, the unit pri
unit pyramid p, the pyramid $v = \dot{a} : \bar{b} : 2c$ a
clinodome $e = \infty \dot{a} : \bar{b} : 2c$. Angles:

87°; $pp = 116°\ 29'$; $vv = 91°\ 26'$; $ee = 72°\ 36'$. Optically +. Axial plane *b*.

Physical Characters. H., 6.5 to 7. Sp. gr., 3.13 to 3.20.
LUSTRE, vitreous. TRANSPARENT to opaque.
STREAK, white. TENACITY, brittle.
COLOR, white, pale-green, emerald, green, pink, purple.

BEFORE BLOWPIPE, ETC.—Becomes opaque, intumesces, swells and fuses to a white or colorless glass, coloring the flame purple-red, especially with hydrochloric acid. Insoluble in acids.

SIMILAR SPECIES.—Distinguished by its tendency to split into thin pearly plates and by the red flame.

REMARKS.—Occurs in granitic rocks with garnet, tourmaline and the granite minerals, quartz, feldspars and micas. It alters readily to a mechanical mixture of albite and mica. Important localities are Stony Point, N. C.; Chesterfield and Huntington, Mass.; Branchville, Conn.; Pennington County, S. D., etc.

USES.—The variety Hiddenite is used as a gem.

JADEITE.

COMPOSITION.—$NaAl(SiO_3)_2$.

GENERAL DESCRIPTION.—Tough, compact translucent material of dark to pale green color.

PHYSICAL CHARACTERS.—Translucent. Lustre, vitreous to pearly. Color, shades of green to nearly white. Streak, white. Very tough. H., 6.5–7. Sp. gr., 3.33–3.35.

BEFORE BLOWPIPE, ETC.—Fuses easily to a transparent glass. Not attacked by acids.

USES.—Is used as an ornamental stone. Also in prehistoric implements and ornaments.

REMARKS.—It is one of the minerals included in the term jade, and occurs in place in Burma and possibly in China.

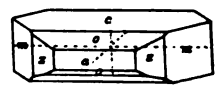
WOLLASTONITE.

COMPOSITION.—$CaSiO_3$.

GENERAL DESCRIPTION.—Cleavable to fibrous white or gray masses. Also in monoclinic crystals, near pyroxene in angle. Sometimes compact. Usually intermixed with calcite.

CRYSTALLIZATION.—Monoclinic. Axes $\dot{a} : \bar{b} : \dot{c} = 1.053 : 1 : 0.967$; $\beta = 84°\ 30'$.

FIG. 601.



Harrisville, N. Y.

Common forms: unit prism *m*, unit dome *o*, pinacoids *a* and *c* and prism $z = \dot{a} : \frac{8}{2}\bar{b} : \infty c$. Angles are: $mm = 87°\ 18'$; $zz = 110°\ 6'$; $c\bar{o} = 139°\ 57'$. Optically—. Axial plane *b*.

Physical Characters. H., 4.5 to 5. Sp. gr., 2.8 to 2.9.

LUSTRE, vitreous to silky. TRANSLUCENT

STREAK, white. TENACITY, br

COLOR, white, gray, or light tints of yellow, red, brown.

CLEAVAGE.—O and $i-\bar{i}$ at angle of 84° 30′.

BEFORE BLOWPIPE, ETC.—Fuses with difficulty, colori flame red. Soluble in hydrochloric acid, generally effer and always gelatinizing.

SIMILAR SPECIES.—Differs from pectolite and natrolite flame, difficulty of fusion, and absence of water. Tremoli not gelatinize.

REMARKS.—Occurs in granular limestone, granite, basalt, lava, etc., with calcite, garnet, etc. By the action of carbonated or sulphurated waters it to calcite or gypsum.

PECTOLITE.

COMPOSITION.—$HNaCa_3(SiO_3)_3$.

GENERAL DESCRIPTION.—White or gray radiating needles and fibres of all lengths up to one yard. Also in tough compact masses and rarely in monoclinic crystals.

PHYSICAL CHARACTERS.—Translucent to opaque. Lustre, vitreous or silky. Color, white or gray. Streak, white. H., 5. Sp. gr., 2.68 to 2.78. Brittle.

BEFORE BLOWPIPE, ETC.—Fuses easily to a white enamel. Yields water in closed tube. Gelatinizes with hydrochloric acid.

FIG. 602.

Weehawken, N. J.

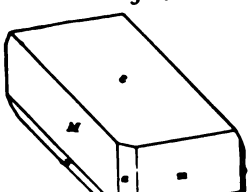
REMARKS.—Occurs with zeolites, prehnite, etc., in cavities and seams of rocks.

RHODONITE.

COMPOSITION.—$MnSiO_3$, with replacement by Fe, Zn or

GENERAL DESCRIPTION.—Brownish red to bright re grained or cleavable masses and disseminated grains, often nally coated with a black oxide. Som in triclinic crystals either tabular par c or sometimes like the forms of py

FIG. 306.



Franklin Furnace.

CRYSTALLIZATION.—Fig. 603 show pinacoids a, b and c, the hemi unit pr and M, and two quarter pyramids r, of $a : b : 2c$. The important angl $mM = 87° 32′$; $cm = 111° 15′$, $93° 37′$.

Physical Characters. H., 5.5 to 6.5. Sp. Gr., 3.4 to 3.68.

LUSTRE, vitreous. TRANSPARENT to opaque.

STREAK, white. TENACITY, brittle.

COLOR, brownish-red to flesh-red, bright-red, greenish, yellowish.

CLEAVAGE, prismatic, angle 87° 38′ and basal.

BEFORE BLOWPIPE, ETC.—Blackens and fuses easily with slight intumescence. With fluxes reacts for manganese and zinc. In powder is partially dissolved by hydrochloric acid, leaving a white residue. If altered may effervesce slightly during solution.

SIMILAR SPECIES.—Rhodochrosite is infusible, dissolves completely with effervescence in warm acids. Red feldspars are less fusible, and do not give manganese reactions.

REMARKS.—Occurs with iron-ore, franklinite, tetrahedrite, etc., and is altered by light, air, and carbonated waters to the oxides and the carbonates.

AMPHIBOLE.—Hornblende.

COMPOSITION.—$RSiO_3$, R generally stands for more than one of the elements, Ca, Mg, Fe, Al, Na and K.

GENERAL DESCRIPTION.—Monoclinic crystals usually with acute rhombic section; columnar, fibrous and granular masses, rarely lamellar, sometimes radiated. Colors white, shades of green, brown, and black.

FIG. 604.

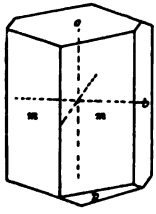
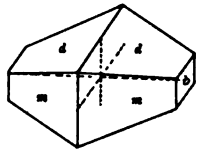
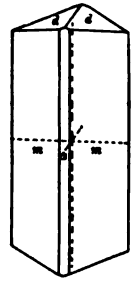


FIG. 605.



Russell, N. Y.

FIG. 606.



CRYSTALLIZATION.—Monoclinic. Axes $\dot{a} : \bar{b} : \dot{c} = 0.551 : 1 : 0.294$; $\beta = 73° 58'$.

Common forms: unit prism *m*, pinacoids *b*, *c* and sometimes *a*, unit clino dome *d* and unit pyramid *p*. Angles are: $mm = 124° 11'$; $cm = 104° 8'$; $dd = 148° 28'$; $pp = 148° 19'$. Twinning as in pyroxene, p. 359.

Optically +, axial plane *b*. Strong double refraction. Often strongly pleochroic.

Physical Characters. H., 5 to 6. Sp. gr., 2.9 to 3.4.

LUSTRE, vitreous to silky. TRANSPARENT to opaq

STREAK, white or greenish. TENACITY, brittle to t

COLOR, white, gray, green, black, brown, yellow and red

CLEAVAGE, prismatic, angle of 124° 11′.

BEFORE BLOWPIPE, ETC.—Varies. Usually fuses easi colored glass, which may be magnetic. Not affected by a

VARIETIES:

Tremolite.—$CaMg_3(SiO_3)_4$, white to gray in color.

Actinolite.—$Ca(Mg.Fe)_3(SiO_3)_4$, bright green or grayish-g

Hornblende and Edenite.—Aluminous varieties, black o in color, with lustre something like horn.

All of these occur in crystals and columnar to fibrous.

Nephrite or Jade is compact and extremely tough, mic cally fibrous, may have composition of tremolite or actino

Asbestus is in fine, easily separable fibres, white, gray, or g

SIMILAR SPECIES.—Differs from tourmaline in cleavage line form and tendency to separate into fibres. The dif between it and pyroxene are:

Amphibole, prism angle and cleavage 124°; tough, o rous, rarely lamellar, often blade-like or pseudo-hexagonal Pyroxene, prism and cleavage angle 87°; brittle, rarely often lamellar crystals, square or octagonal.

REMARKS.—Occurs with pyroxene, serpentine, talc, magnetite, quartz, spars, etc., and forms by alteration, epidote, serpentine, talc, chlorite, iron-o

Much of the material passing under the name of asbestus is fibrous serpent best of the pure material is imported from Germany and Italy. Producing the United States are located in California, Wyoming and Oregon. North Georgia, Pennsylvania and other States have large deposits, but the quality of occurrence do not allow it to be profitably mined at present. For most the fibrous serpentine of Canada is superior to any American asbestus.

Uses.—Asbestus is made into cloth and boards, which combustible and are good non-conductors of heat. It is roofing, coverings for steam pipes, piston packing, theatre c firemen's suits, fire-proof paints and cements, and for lining s is made into yarns, ropes and paper for fire-proof purposes.

Nephrite or jade has had many uses in prehistoric times historic times among semi-civilized or non-civilized nations the toughest of all known stones and in the stone age w

for weapons and tools. In China and India and in ancient Mexico it was carved into ornaments, symbols of authority, sacrificial vessels, etc. It has had a false value as a cure for kidney diseases, and both its names are derived from words meaning "kidneys."

Glaucophane. A sodium amphibole $NaAl(SiO_3)_2.FeMgSiO_3$ blue in color and occurring in indistinct prisms or in columnar and fibrous masses especially in metamorphic schists. Crystals show distinctly different colors when viewed by transmitted light through different faces.

Uralite. An amphibole pseudomorphic after pyroxene, having the crystal form of pyroxene and cleavage of amphibole.

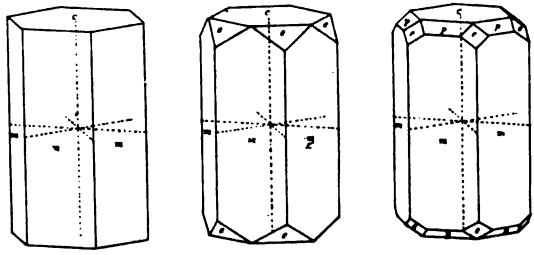
Crocidolite. A blue to green asbestos like amphibole. An altered South African form of the compact mineral which has a peculiar changeable lustre is often used as a cheap gem under the name of "tiger's eye."

BERYL.—Emerald, Aquamarine.

COMPOSITION.—$Gl_3Al_2(SiO_3)_6$.

GENERAL DESCRIPTION.—Hexagonal prisms, from mere threads to several feet in length. Usually some shade of green. Sometimes in columnar or granular masses. Harder than quartz.

FIG. 610. FIG. 607. FIG. 608.



CRYSTALLIZATION.—Hexagonal. Axis $c = 0.499$. Usually prism m with base c sometimes with unit pyramid p or second order form $e = 2a : 2a : a : 2c$. Angles $cp = 150° 4'$; $ce = 135° 4'$.

Optically —. Low refraction and very low double refraction ($\alpha = 1.5659$; $\gamma = 1.5703$ for yellow light).

Physical Characters. H., 7.5 to 8. Sp. gr., 2.63 to 2.8.

LUSTRE, vitreous. TRANSPARENT to nearly opaque.

STREAK, white. TENACITY, brittle.

COLOR, emerald to pale-green, blue, yellow, white, red, colorless.

CLEAVAGE, imperfect basal and prismatic.

BEFORE BLOWPIPE, ETC.—Fuses on thin edges, often becoming white and translucent. Slowly dissolved in salt of phosphorus to an opalescent bead. Insoluble in acids.

VARIETIES.

Emerald.—Bright emerald green, from the presence of chromium.

Aquamarine.—Sky-blue to greenish-blue.

Goshenite.—Colorless.

SIMILAR SPECIES.—Harder than apatite, quartz or tour Differs in terminal planes from quartz. Lacks distinct cl of topaz.

REMARKS.—Occurs in granite, mica-schist, clay-slate, etc., frequently pe the other minerals, showing that it was formed before them. It is associ quartz, micas, feldspars, garnet, corundum, zircon, etc. By alteration, it fo linite, muscovite, etc. Beryls are especially abundant at Ackworth and Grafto Royalston, Mass.; Paris and Stoneham, Me.; Alexander County, N. C.; t Hills of South Dakota, and Litchfield, Conn. Those at Ackworth and Gr sometimes of immense size. One crystal, near the railroad station of Grafto measures 3 feet 4 inches by 4 feet 3 inches on horizontal section. and is ex over 5 feet. Good emeralds have been obtained in this country from A County, S. C., and especially from Stony Point. Aquamarines and other g mens have been obtained at Paris and Stoneham, Me.; Mount Antero, C several places in North Carolina. Emeralds of finest quality are obtained n United States of Colombia, also from India, Brazil, Siberia and Australia.

USES.—Emerald and aquamarine are cut as gems.

CYANITE.—Kyanite

FIG

COMPOSITION. — $(AlO)_2SiO_3$, probably a basic metasilicate.*

GENERAL DESCRIPTION.—Found in long triclinic blade-like crystals, rarely with terminal planes. The color is a blue, deeper along the center of the blades, and at times passes into green or white.

Physical Characters. H., 5 to 7. Sp. gr., 3.56 to 3.67.

LUSTRE, vitreous. TRANSLUCENT to transpa

STREAK, white. TENACITY, brittle.

COLOR, blue, white, gray, green to nearly black.

CLEAVAGE, parallel to the three pinacoids.

BEFORE BLOWPIPE, ETC.—Infusible, with cobalt soluti comes blue. Insoluble in acids.

REMARKS.—Occurs chiefly in gneiss and mica schist, and must have bee below 1300°, as at this temperature it is changed into fibrolite, It is associ pyrophyllite, andalusite, corundum, etc., and is found throughout the regions of Massachusetts, Pennsylvania, North Carolina, and Georgia.

* Dana places cyanite with the orthosilicates for convenience.

IOLITE.—Dichroite, Cordierite.

COMPOSITION.—$Mg_3(Al.Fe)_6(SiO_4)_4(SiO_3)_4$.

GENERAL DESCRIPTION.—Short, six- or twelve-sided orthorhombic prisms and massive, glassy, quartz-like material. Usually blue in color. The color is often deep blue in one direction and gray or yellow in a direction at right angles with the first.

PHYSICAL CHARACTERS.—Transparent or translucent. Lustre, vitreous. Color, light to smoky blue, gray, violet or yellow. Dichroic. Streak, white. H., 7 to 7.5. Sp. gr., 2.6 to 2.66. Brittle. Cleaves parallel to brachy pinacoid.

BEFORE BLOWPIPE, ETC.—Fuses with difficulty, becoming opaque. With cobalt solution becomes blue-gray. Partially soluble in acids.

REMARKS.—Occurs in gneiss and sometimes in granite, rarely in volcanic rocks, and is formed by contact with igneous matter. It is easily altered to a soft lamellar or fibrous material of green or yellow color, and is rarely found entirely unaltered.

ORTHOSILICATES.

The ORTHOSILICATES are derivatives of H_4SiO_4, as Zircon, $ZrSiO_4$; Phenacite, Gl_2SiO_4. Isomorphic mixtures are well represented by Biotite, $(H.K)_2(Mg.Fe)Al_2(SiO_4)_3$; acid salts by Prehnite, $H_2Ca_2Al_2(SiO_4)_3$, and basic salts by Sillimanite, $Al(AlO)SiO_4$. Haüynite is an example of a crystalline mixture of an orthosilicate and a sulphate. As a rule, the orthosilicates are less stable than the metasilicates.

The orthosilicates described here are: NEPHELITE, HAÜYNITE, LAZURITE, GARNET, CHRYSOLITE, PHENACITE, WERNERITE, VESUVIANITE, ZIRCON, TOPAZ, ANDALUSITE, SILLIMANITE, DATOLITE, EPIDOTE, ALLANITE, PREHNITE.

BIOTITE, PHLOGOPITE and MUSCOVITE, although derivatives of orthosilicic acid, are, according to the system of Dana, classified as hydrous silicates, while the probable orthosilicates, CHONDRODITE and STAUROLITE are classed as subsilicates.

NEPHELITE.—Elæolite.

COMPOSITION.—$7NaAlSiO_4 + NaAl(SiO_3)_2$. With partial replacement of Na by K or Ca.

GENERAL DESCRIPTION.—Small, glassy, white or colorless grains or hexagonal prisms with nearly flat ends, in lavas and eruptive rocks, or translucent reddish-brown or greenish masses and coarse crystals, with peculiar greasy lustre.

Physical Characters. H., 5.5 to 6. Sp. gr., 2.55 to 2.65.

LUSTRE, vitreous or greasy. TRANSPARENT to opaque.

STREAK, white. TENACITY, brittle.

COLOR, white, colorless, reddish, brownish, greenish or gray.

CLEAVAGE, prismatic and basal.

BEFORE BLOWPIPE, ETC.—Fuses to a colorless glass. When heated with cobalt solution, becomes blue. Soluble in hydrochloric acid, with residue of gelatinous silica.

VARIETIES.—The usually massive varieties, with greasy lustre, are called elæolite.

REMARKS.—Nephelite occurs in eruptive rocks and lavas. Elæolite occurs in granular, crystalline rocks such as syenite. Nephelite alters easily and is the source of many of the zeolites. Austin, Texas; Litchfield, Me., and the Ozark Mountains, Arkansas, are important localities of elæolite. Nephelite is abundant in the lavas of Vesuvius.

CANCRINITE.

COMPOSITION.—$H_6Na_6Ca(Na_2CO_3)_2Al_6(SiO_4)_9$.

GENERAL DESCRIPTION.—A yellow to white (rarely blue) massive mineral usually associated with elæolite and blue sodalite. Rarely in hexagonal prisms. Optically —.

PHYSICAL CHARACTERS.—Translucent to transparent. Lustre, vitreous. Color, yellow, pink, blue, green, gray and white. Streak, white. H., 5–6. Sp. gr., 2.4–2.5.

BEFORE BLOWPIPE, ETC.—Fuses easily with bubbling to a white glass. Yields water in closed tube. Effervesces in HCl when warmed, and if previously ignited it yields a jelly on evaporation.

REMARKS.—Found at Litchfield and Gardiner, Me.; Miask, Urals; Brevik, Norway and other localities.

SODALITE.

COMPOSITION.—$Na_4(AlCl)Al_2(SiO_4)_3$.

GENERAL DESCRIPTION —Bright blue to gray masses and embedded grains. Concentric nodules resembling chalcedony and rarely dodecahedral crystals sometimes of a pale pink color.

PHYSICAL CHARACTERS.—Transparent to translucent. Lustre, vitreous to greasy. Color, blue, gray, nearly white, pale pink. Streak, colorless. H., 5.5 to 6. Sp. gr., 2.14–2.30. Brittle. Cleavage, dodecahedral. Index of refraction, yellow light, 1.4827.

BEFORE BLOWPIPE, Etc.—Fuses to a colorless glass. In closed tube the blue varieties become white and opaque. Soluble in hydrochloric acid with gelatinization.

REMARKS.—Found at Litchfield, Me., various localities in Montana, Quebec, and Ontario; also occurs in Vesuvius lavas, at Kaiserstuhl, Baden; and Miask, Urals.

HAÜYNITE.

COMPOSITION.—$2(Na_2Ca)Al_2(SiO_4)_2$. $(Na_2.Ca)SO_4$ possibly, but very complex and with varying proportions of Na and Ca.

GENERAL DESCRIPTION.—Glassy blue to green imbedded grains, or rounded isometric crystals in igneous rock.

PHYSICIAL CHARACTERS.—Translucent. Lustre, vitreous or greasy. Color, blue, green, red, yellow. Streak, white. H. 5.5 to 6. Sp. gr., 2.4 to 2.5. Brittle.

BEFORE BLOWPIPE, ETC.—Fuses slowly to a white glass, which will blacken silver. Gelatines with hydrochloric acid.

Noselite.—Like haüynite but containing little or no lime.

LAPIS LAZULI or LAZURITE.—Native Ultramarine.

COMPOSITION.—An orthosilicate of sodium and aluminium, with a sulphate and a polysulphide of sodium.

GENERAL DESCRIPTION.—Deep-blue masses intimately mixed with other minerals. Rarely in isometric forms.

PHYSICAL CHARACTERS.—Translucent. Lustre, vitreous. Color, deep-blue, violet and greenish-blue. Streak, white. H., 5 to 5.5. Sp. gr., 2.38 to 2.45. Brittle.

BEFORE BLOWPIPE, ETC.—Fuses easily to a white glass, with intumescence. In closed tube, glows with a green light and yields water. Soluble in hydrochloric acid with evolution of hydrogen sulphide and residue of gelatinous silica.

USES.—It is employed in inlaid work, and before the invention of artificial ultramarine it was very valuable as a durable, deep blue, color for oil paintings.

GARNET.

COMPOSITION.—$R''_3R'''_2(SiO_4)_3$. R'' is Ca, Mg, Fe or Mn. R''' is Al, Fe''' or Cr, rarely Ti.

GENERAL DESCRIPTION.—Imbedded isometric crystals, either complete or in druses and granular, lamellar and compact masses. Usually of some brown, red or black color, but occurring of all colors except blue, and harder than quartz. Also found in alluvial material as rounded grains.

FIG. 611.

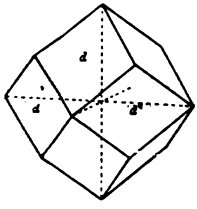


FIG. 612.

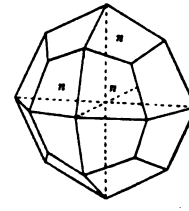


FIG. 613.

Fort Wrangell, Alaska.

FIG. 614.

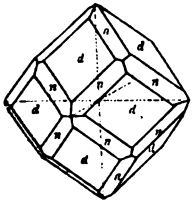


FIG. 615.

CRYSTALLIZATION.—Isometric. Usually a combinati
dodecahedron d and the tetragonal trisoctahedron, $n =$
Fig. 614, or these as simple forms, Figs. 611, 612, or m
with the hexoctahedron, $s = a : \frac{3}{2}a : 3a$. Index of refr
red light 1.7645 to 1.7716.

Physical Characters. H., 6.5 to 7.5. Sp. gr.,* 3.15
LUSTRE, vitreous or resinous. TRANSPARENT to o
STREAK, white. TENACITY, brittle to
COLOR, brown, black, violet, yellow, red, white, green.
CLEAVAGE, dodecahedral, imperfect.

BEFORE BLOWPIPE, ETC.—Fuses rather easily to lig
glass, except in case of infusible chromium and yttrium
Insoluble before fusion, but after fusion will usually gelat
hydrochloric acid. Bead reactions vary with compositi

VARIETIES.

Grossularite.—$Ca_3Al_2(SiO_4)_3$. White, pale yellow, p
brown-red rose-red.

Pyrope.—$Mg_3Al_2(SiO_4)_3$ Deep-red to nearly black, of
parent.

Almandite.—$Fe_3Al_2(SiO_4)_3$. Fine deep-red to black.
part of precious and of common garnet.

Spessartite.—$Mn_3Al_2(SiO_4)_3$. Brownish-red to purplish
red.

Andradite.—$Ca_3Fe_2(SiO_4)_3$. Yellow, green, red, brow
Includes many of the common garnets.

Uvarovite.—$Ca_3Cr_2(SiO_4)_3$. Emerald green, small crys

REMARKS.—Garnet is common in schists, gneiss, etc., and also occurs
limestone, serpentine, and even in volcanic rocks. By oxidation of their
and by the action of carbonated waters, garnets are altered, forming calcit
soapstone, serpentine, gypsum, etc. The common garnet is a very comm
in many localities throughout the United States. Precious garnets are fo
Navajo Reservation, New Mexico; in Southern Colorado, Arizona, U
County, Ky.; Amelia County, Va.; Oxford County, Me.; and in Nort
Georgia, Montana, Idaho and Alaska. In Lewis and Warren Counties, N.
County, Ga., and Burke County, N. C., garnets are so plentiful that they
for use as an abrasive.

USES.—Thousands of tons are used as an abrasive ma
termediate in hardness between quartz and corundum.

* Magnesium varieties lightest.

containing large pink garnets is quarried at Morelos, Mexico, as an ornamental stone. Transparent red garnets are sometimes highly valued as gems, and the green variety is also sometimes cut.

CHRYSOLITE.—Olivine, Peridot.

COMPOSITION.—$(Mg.Fe)_2SiO_4$.

GENERAL DESCRIPTION.—Transparent to translucent, yellowish-green granular masses, or disseminated glassy grains, or olive-green sand. When containing much iron, the color may be reddish-brown, or even, by alteration, opaque-brown or opaque-green. Rarely in orthorhombic crystals.

CRYSTALLIZATION.—Orthorhombic. Axes $\breve{a} : \bar{b} : \dot{c} = 0.4657 : 1 : 0.5865$. Fig. 616 shows the pinacoids *a*, *b* and *c*, the unit forms of pyramid, prism, macro and brachy dome *m*, *p*, *o* and *d*, the macro prism $l = \breve{a} : 2\bar{b} : \infty c$ and macro pyramid $q = \breve{a} : 2\bar{b} : c$.

Prominent angles are $mm = 130° 3'$; $pp = 139° 55'$; $co = 128° 27'$; $cd = 130° 27'$.

FIG. 616.

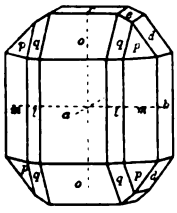


FIG. 617.

Optically +. Axial plane *c*. Acute bisectrix normal to *a*. Strong refraction and double refraction ($\beta = 1.678$ and $2V = 87° 46'$, for yellow light).

In thin rock sections, Fig. 617, the outline, the distinct cleavage cracks and the frequent partial alteration to serpentine assist in its recognition.

Physical Characters, H., 6.5 to 7. Sp. gr., 3.27 to 3.57.

LUSTRE, vitreous. TRANSPARENT to translucent.

STREAK, white or yellowish. TENACITY, brittle.

COLOR, yellowish-green to brownish-red.

BEFORE BLOWPIPE, ETC.—Loses color, whitens, but is infusible unless proportion of iron is large, when it fuses to a magnetic globule. Soluble in hydrochloric acid with gelatinization of silica.

SIMILAR SPECIES.—Differs by gelatinization from green pyroxene. Is harder than apatite and less fusible than to

REMARKS.—Of igneous origin, occurring in basalts, traps and crystal associated with such minerals as pyroxene, enstatite, amphibole, labradorit etc. By alteration of its ferrous iron and by hydration forms limonite and and the excess of magnesia usually forms magnesite. Further change m serpentine to magnesite, leaving quartz or opal. Found at Thetford, V N. C., Waterville, N. H., also in Virginia, Pennsylvania, New Mexico, C Small gems are found in the garnet and sapphire regions of New Mexic Colorado, and Montana.

USES.—Transparent varieties are sometimes cut as gem

HYALOSIDERITE.—A highly ferruginous variety of chrysolite, containin as high as thirty per cent. of ferrous oxide.

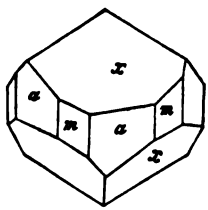
FAYALITE.—Has nearly all of the Mg replaced by Fe so that the compos of a simple iron orthosilicate. H., 6.5. Sp. gr., 4.32. Fuses to a magn

PHENACITE.

COMPOSITION.—Gl_2SiO_4 (GlO 45.55, SiO_2 54.45 per cent.).

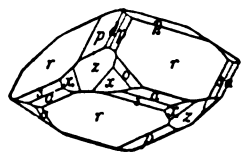
GENERAL DESCRIPTION.—Colorless, transparent, rhombohedral cryst small, frequently lens shaped. Sometimes yellowish and sometimes in pris Harder than quartz.

FIG. 618.



Mt. Antero, Col.

FIG. 619.



Florissant, Col.

CRYSTALLIZATION.—Hexagonal. Class of third order rhombohedron p $\dot{c}$ = 0.661. Prominent angles $x\,x = 104° 3'$; $r\,r = 116° 36'$. Optically

PHYSICAL CHARACTERS.—Transparent to nearly opaque. Lustre, vitreo colorless, yellow, brown. Streak, white. H., 7.5 to 8. Sp. gr., 2.97 to Cleavag , prismatic.

BEFORE BLOWPIPE, ETC.—Infusible and unaffected by acids. Made d cobalt solution.

REMARKS.—Occurs with amazon stone, beryl, quartz, topaz, emerald, sometimes used as an imitation gem.

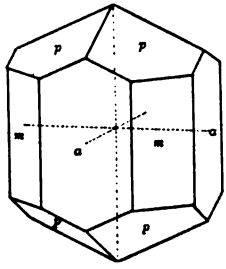
WERNERITE.—Scapolite.

COMPOSITION.—A silicate of calcium, and aluminum, of composition and containing also soda and chlorine.

GENERAL DESCRIPTION.—Coarse, thick, tetragonal usually quite large and dull and of some gray, green, c

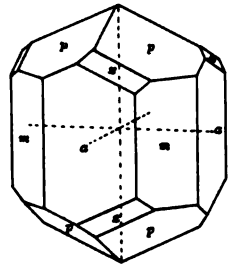
color. Cleavage surfaces have a characteristic fibrous appearance. Also in columnar and granular masses.

FIG. 620.



Usual form.

FIG. 621.



Meionite of Vesuvius.

CRYSTALLIZATION.—Tetragonal. Class of third order pyramid, p. 29. Axis $\dot{c} = 0.438$. Usually prisms of first order *m*, and second order *a*, and unit pyramid *p*. Angle $pp = 136° 15'$. Optically —, with weak refraction and double refraction.

Physical Characters. H., 5 to 6. Sp. gr., 2.66 to 2.73.

LUSTRE, vitreous to dull. OPAQUE to translucent.

STREAK, white. TENACITY, brittle.

COLOR, gray, green, white, bluish, reddish.

CLEAVAGE., parallel to both prisms.

BEFORE BLOWPIPE, ETC.—Fuses with intumescence to a white glass containing bubbles. Imperfectly soluble in hydrochloric acid.

REMARKS.—Wernerite has been formed by heat at or near fusion. It is most abundant in granular limestone near contact with granite or similar rock. It occurs with pyroxene, apatite, garnet, zircon, biotite, etc., and is changed to pinite, mica, talc, etc., by atmospheric influence. Especially abundant at Bolton, Mass. Other localities common in New England, New York, New Jersey and elsewhere.

VESUVIANITE.—Idocrase.

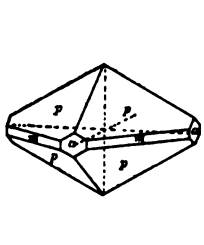
COMPOSITION.—$Ca_6[Al(OH, F)]Al_2(SiO_4)_6$ with replacement of Ca by Mn, and Al by Fe.

GENERAL DESCRIPTION.—Brown or green, square and octagonal prisms and radiated columnar masses. Less frequently in pyramidal forms or granular or compact.

CRYSTALLIZATION.—Tetragonal. Axis $\dot{c} = 0.537$. Usually the unit prism *m* with base *c* and unit pyramid *p*. Prismatic faces often vertically striated. Angles $pp = 129° 21'$; $cp = 142° 46'$.

Optically—(rarely +) with rather strong refraction
double refraction ($\alpha = 1.7226$; $\gamma = 1.7325$ for yellow li

FIG. 622. FIG. 623. FIG



Monzoni, Tyrol.

Physical Characters. H., 6.5. Sp. gr., 3.35 to 3.45.
LUSTRE, vitreous to resinous. TRANSLUCENT to
STREAK, white. TENACITY, brittle
COLOR, brown or green, rarely yellow or blue Dichr
CLEAVAGE, indistinct, prismatic and basal.

BEFORE BLOWPIPE, ETC.—Fuses easily with intumes
green or brown glass. At high heat yields water in
tube. Very slightly affected by hydrochloric acid, but
tion is dissolved leaving a gelatinous residue.

SIMILAR SPECIES.—The crystals and the columnar stru
tinguish it from epidote, tourmaline, or garnet. The
not often like those of pyroxene.

REMARKS.—Vesuvianite occurs most frequently in metamorphic ro
limestone, serpentine, chlorite, gneiss, etc., with garnet, muscovite, ca
alters to talc, serpentine and calcite. Found at Parsonsfield and Rumfo
Warren, N. H., Newton, N. J., Amity, N. Y. Also in California,
Quebec.

MELILITE.

COMPOSITION.—$Ca_{12}Al_4(SiO_4)_2$ with Na, Mg and Fe replacing Ca and
GENERAL DESCRIPTION.—Occurs in short prisms and in tabular ortho
tals, especially in leucite and nephelite rocks and in melilite basalt.
PHYSICAL CHARACTERS.—Transparent to opaque. Lustre, vitreous.
yellow to brown, green and white. Brittle. H. 5. Sp. gr., 2.9.
BEFORE BLOWPIPE, ETC.—Fuses quite easily to a yellowish or green g
Gelatinizes with hydrochloric acid.

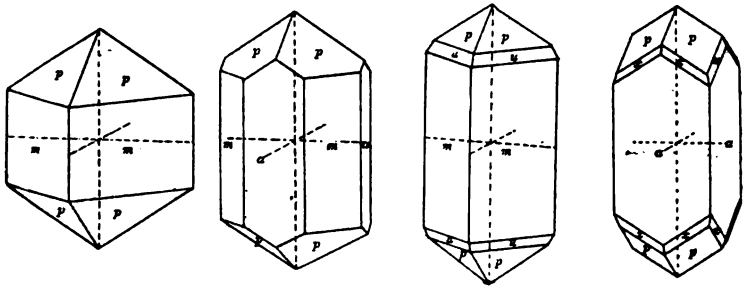
ZIRCON.—Hyacinth.

COMPOSITION.—$ZrSiO_4$ (ZrO 67.2, SiO_2 32.8 per cent.
GENERAL DESCRIPTION.—Small, sharp cut, square p
pyramids with adamantine lustre and brown or gray
Sometimes in large crystals and in irregular lumps and

CRYSTALLIZATION.—Tetragonal. Axis $\dot{c} = 0.640$. Common forms: unit prism m, unit pyramid p, second order prism a, and pyramids $u = a : a : 3c$ and $x = a : 3a : 3c$. Angles $pp = 123° 19'$; $uu = 96° 51'$; $mu = 159° 48'$; $ax = 148° 7'$.

Optically + with strong refraction and double refraction ($\alpha = 1.9239$; $\gamma = 1.9628$ for yellow light).

FIG. 625. FIG. 626. FIG. 627. FIG. 628.



Physical Characters. H., 7.5. Sp. gr., 4.68 to 4.70.

LUSTRE, adamantine. TRANSPARENT to opaque.

STREAK, white. TENACITY, brittle.

COLOR, brown, reddish, gray, colorless, green, yellow.

CLEAVAGES, imperfect, parallel to both pyramid and the prism.

BEFORE BLOWPIPE, ETC.—Infusible, losing color and sometimes becoming white. Insoluble in acids or in soda.

REMARKS.—Zircon is one of the first formed rock constituents, and is common as an enclosure in the others, especially the older eruptive rocks, granular limestone, schists, gneiss, syenite, granite, and iron-ore. It is also found in alluvial deposits.

Zircons have been mined at Green River, Henderson county, N. C., where they are especially abundant. Specimen localities are common throughout the United States and Canada.

USES.—As a source of zirconium oxide used in one variety of incandescent light. Transparent, red and brown varieties are cut under the name of hyacinth. Colorless or smoke varieties are called jargon, and are comparatively worthless.

TOPAZ.

COMPOSITION.—$Al_{12}Si_6O_{25}F_{10}$ or $Al(Al(O.F_2))SiO_4$.

GENERAL DESCRIPTION.—Hard, colorless or yellow transparent orthorhombic crystals with easy basal cleavage. Also massive in columnar aggregates, and as rolled fragments and crystals in alluvial deposits.

CRYSTALLIZATION.—Orthorhombic. $\breve{a} : \bar{b} : \dot{c} = 0.529 : 1 : 0.477$

Prisms often vertically striated. Crystals rarely doubly terminated. The predominating forms are the unit prism *m*, brachy

FIG. 629.

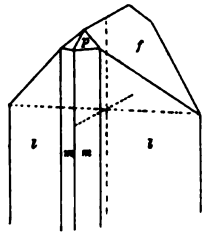


FIG. 630.

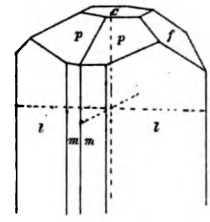
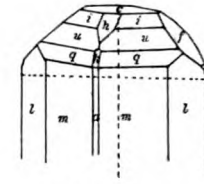


FIG. 631.



Omi, Japan.

prism $l = 2\,\breve{a} : b : \infty\, c$ (with predominance of *l* the section is often nearly square); base *c*, unit pyramid *p* and dome $f = \infty\,\breve{a} : \bar{b} : 2\,\dot{c}$.

Prominent angles are: $mm = 124° 17'$; $ll = 86° 49'$; $pp = 141°$ ff (top) $= 92° 42'$.

Optically +. Axial plane *b*. Acute bisectrix normal to *c*. Refractive indices and axial angles vary considerably for different localities.

Physical Characters. H., 8. Sp. gr., 3.4 to 3.65.

LUSTRE, vitreous. TRANSPARENT to nearly opaque.

STREAK, white. TENACITY, brittle.

COLOR, colorless, yellow, pale-blue, green, white, pink.

CLEAVAGE, basal perfect.

BEFORE BLOWPIPE, ETC.—Infusible, but yellow varieties may become pink. With cobalt solution the powder becomes blue. Slowly dissolved in borax. If powdered and heated with previously fused salt of phosphorus in open tube the glass will be etched. Insoluble in acids.

REMARKS.—Probably always formed under the influence of heat. Occurs with minerals of similar origin in granite and gneiss, or less frequently in cavities in volcanic rock. Associates are the granite minerals and apatite, fluorite, cassiterite, beryl, zircon, etc.

Fine crystals of Topaz are found at Deseret, Utah, at Crystal Park, Cheyenne, and Devil's Head Mountain, Colo., Nathrop, Cal., Stoneham, Me., and Bald Mountain, N. H. Gems are also obtained from Siberia, Brazil, Japan, Australia, Mexico and other countries.

USES.—Transparent varieties are cut as gems.

ANDALUSITE.—Chiastolite.

COMPOSITION.—$Al(AlO)SiO_4$, (Al_2O_3 63.2, SiO_2 36.8 per cent.)

GENERAL DESCRIPTION.—Coarse, nearly square prisms of pearl gray or pale red color, or in very tough, columnar or granular masses. An impure soft variety (chiastolite) occurs in rounded prisms, any cross section of which shows a cross or checkered figure, due to the symmetrical deposition of the impurities, Figs. 633 and 320.

FIG. 632.

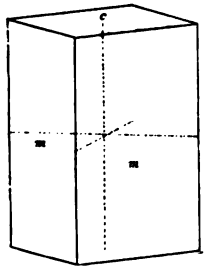
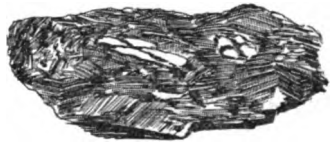
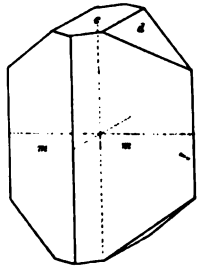


FIG. 633.



Chiastolite, Sterling, Mass.

FIG. 634.



CRYSTALLIZATION.—Orthorhombic. Axes $\dot{a} : \dot{b} : \dot{c} = 0.986 : 1 : 0.702$. Usually either the unit prism *m*, and base *c*, or these with the unit brachy dome *d*. Angles are $mm = 90° 48'$; $dd = 109° 50'$.

Optically —. Axial plane the brachy pinacoid. Acute bisectrix normal to *c*. Colored varieties strongly pleochroic.

Physical Characters. H., 7 to 7.5. Sp. gr., 3.16 to 3.20.

LUSTRE, vitreous. TRANSPARENT to opaque.

STREAK, white. TENACITY, brittle to tough.

COLOR, rose-red, flesh-red, violet, pale green, white, pearl-gray.

CLEAVAGE, prismatic, imperfect at angle of 90° 48′.

BEFORE BLOWPIPE, ETC.—Infusible. In powder becomes blue with cobalt solution. Insoluble in acids.

REMARKS.—It occurs in clay slates and in gneiss and schists with cyanite, fibrolite, quartz, etc. It alters rather readily to cyanite or kaolin. Found in many localities in the New England States, also in Pennsylvania and California. Foreign localities are numerous. Transparent crystals are found in Minas Geraes, Brazil.

SILLIMANITE or FIBROLITE.

COMPOSITION.—$Al(AlO)SiO_4$.

GENERAL DESCRIPTION.—Long, almost fibrous orthorhombic crystals, and fibrous or columnar masses of brown or gray color.

PHYSICAL CHARACTERS.—Transparent to translucent. Lustre, vitreous. Color, brown, gray, greenish. Streak, white. H., 6 to 7. Sp. gr., 3.23 to 3.24. Tough. Cleavage, parallel to brachy pinacoid.

BEFORE BLOWPIPE, ETC.—Infusible, becomes dark blue with cobalt solu soluble in acids.

REMARKS.—Chiefly found in mica schist, gneiss, etc. Sometimes with

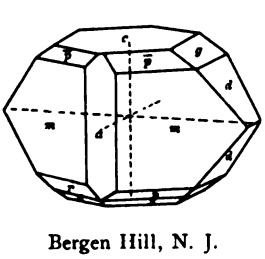
USES.—In the stone age it was used for tools, weapons, etc., being secc jade in toughness.

DATOLITE.

COMPOSITION.—$Ca(B.OH)SiO_4$.

GENERAL DESCRIPTION.—Highly modified, glassy, mc crystals. Usually colorless, but also white or greenish. compact, dull, white or pink masses, resembling unglazed p

FIG. 635. FIG. 636. FIG. 63



Bergen Hill, N. J. Lake Supe

CRYSTALLIZATION.—Monoclinic. $\beta = 89° 51'$. Axes $\dot{a}$ 0.634 : 1 : 1.266. Prominent forms are the pinacoids a the unit prism m, negative unit pyramid $\bar{p}$, unit clinodome prism $l = 2\dot{a} : b : \infty\dot{c}$, and positive hemi pyramid $r = \dot{a}$ Important angles are $mm = 115° 13'$; $ll = 103° 31'$; $\bar{p}\bar{p}$ $55'$; $dd = 76° 37'$.

Physical Characters. H., 5 to 5.5. Sp. gr., 2.9 to 3.

LUSTRE, vitreous. TRANSLUCENT to nearly op

STREAK, white. TENACITY, brittle.

COLOR, colorless, white, greenish.

BEFORE BLOWPIPE, ETC.—In forceps or on charcoal fuse to a colorless glass, and if mixed with a flux of acid po sulphate and calcium fluoride and a little water it will col green. In closed tube yields water at a high heat. So hydrochloric acid, with gelatinization.

SIMILAR SPECIES.—Differs from the zeolites in crystalli and flame.

REMARKS—It is a secondary mineral found in igneous rocks and sometim allic veins. Usually occurs with the zeolites, prehnite, calcite, etc. Found Hill and Paterson, N. J.; at Hartford, Tariffville and Roaring Brook, Conn New York, Michigan, Massachusetts, California, etc.

ZOISITE—Thulite.

COMPOSITION.—$Ca_2 Al_2 (Al.OH) (SiO_4)_3$.

GENERAL DESCRIPTION.—Gray or green and rose red (thulite) columnar and fibrous aggregates. More rarely, deeply striated orthorhombic prisms with indistinct terminations and perfect cleavage parallel the brachy pinacoid.

PHYSICAL CHARACTERS.—Transparent to opaque. Lustre, vitreous to pearly. Color, white, gray, brown, green, pink and red. Streak, white. H., 6–6.5. Sp. gr., 3.25–3.35. Optically +.

BEFORE BLOWPIPE, ETC.—Swells up and fuses easily to a glassy mass which does not readily assume globular form. Not affected by HCl before ignition, but after ignition it is decomposed with formation of jelly.

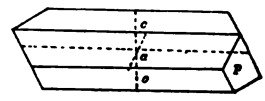
REMARKS.—Found at Ducktown, Tenn., Chesterfield, Mass., Uniontown, Pa., and many other American and foreign localities.

EPIDOTE.

COMPOSITON.—$Ca_2Al_2(AlOH)(SiO_4)_3$ with some iron replacing aluminum.

GENERAL DESCRIPTION.—Coarse or fine granular masses of peculiar yellowish-green color, sometimes fibrous. Also in monoclinic crystals and columnar groups, from yellow-green to blackish-green in color.

FIG. 638.



CRYSTALLIZATION.—Monoclinic. $\beta = 64°37.'$ Axes $\dot{a} : \dot{b} : \dot{c} = 1.579 : 1 : 1.804$. For the forms: m = unit prism, a and c pinacoids, p unit pyramid and o unit dome, the angles are $mm = 70° 4'$; $ca = 115°23'$; $co = 116°18'$. Crystals extended in direction of ortho axis.

Optically —. Axial plane the clino pinacoid. Acute bisectrix nearly vertical. Refraction and double refraction both strong. Pleochroism strong. Sometimes shows colored absorption figure when held close to the eye.

Physical Characters. H., 6 to 7. Sp. gr., 3.25 to 3.5.

LUSTRE, vitreous. TRANSPARENT to opaque.

STREAK, white. TENACITY, brittle.

COLOR, yellowish-green to nearly black and nearly white, also red and gray. CLEAVAGE, basal, easy.

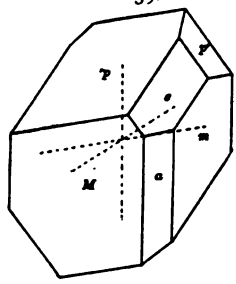
BEFORE BLOWPIPE, ETC.—Fuses easily with intumescence to a dark, usually slightly magnetic, globule. At high heat yields water. Slightly soluble in hydrochloric acid, but if previously ignited, it dissolves, leaving gelatinous silica.

REMARKS.—Formed chiefly by alteration of the feldspars, hornblende or biotite, etc., and is common in many crystalline rocks, often accompanying beds of iron in these rocks. It is not readily altered. Common throughout New England and many of the western States.

PIEDMONTITE.—A red manganiferous epidote. Crystals show different colors by transmitted light when viewed through different planes.

AXINITE.

FG. 639.



COMPOSITION.—An orthosilicate containing especially boron, aluminium, and calcium with some iron and manganese.

GENERAL DESCRIPTION.—Occurs in acute-edged triclinic crystals, see Fig. 639, usually of clove brown, bluish or yellow color. Also occurs lamellar or massive of a bright glassy lustre.

PHYSICAL CHARACTERS.—Translucent to transparent. Luster, highly vitreous. Color brown, bluish, yellow, gray and greenish. Streak, white. H., 6.5–7. Sp. gr., 3.27–3.25. Optically —.

BEFORE BLOWIPPE, ETC.—Fuses easily with bubbling to a dark greenish or black glassy globule. Reacts for boron. Gelatinizes with HCl after ignition.

REMARKS.—Fine crystals are obtained in Bourg d'Oisans, Dauphiné; and Mt. Skopi, Switzerland.

ALLANITE.

COMPOSITION.—Analogous to epidote, but a silicate of the cerium and yttrium groups with lime and iron.

GENERAL DESCRIPTION.—Pitch black or brownish embedded veins and masses and flat tabular or prismatic monoclinic crystals.

PHYSICAL CHARACTERS.—Opaque. Lustre, submetallic or pitch-like. Color, pitch black or brown. Streak, nearly white. H., 5.5 to 6. Sp. gr., 3.5 to 4.2. Brittle.

BEFORE BLOWPIPE, ETC.—Fuses very easily, becoming strongly magnetic, and at high temperature yielding water. Usually gelatinizes with hydrochloric acid, but after ignition is insoluble.

PREHNITE.

COMPOSITION.—$H_2Ca_2Al_2(SiO_4)_3$.

GENERAL DESCRIPTION.—A green to grayish-white vitreous mineral. Sheaf-like groups of tabular crystals, united by the basal planes. Sometimes barrel-shaped crystals and frequently reniform or botryoidal crusts with crystalline surface.

Fig. 640.

Bourg d'Oisans.

Physical Characters. H., 6 to 6.5. Sp. gr., 2.8 to 2.95.

LUSTRE, vitreous. TRANSLUCENT.

STREAK, white. TENACITY, brittle.

COLOR, light to dark green or grayish-white. CLEAVAGE, basal.

BEFORE BLOWPIPE, ETC.—Easily fusible to a whitish glass containing bubbles. In closed tube yields a little water. Soluble in hydrochloric acid, and after *fusion* is soluble with a gelatinous residue.

SIMILAR SPECIES.—Resembles calamine or green smithsonite somewhat, but is more easily fused, and does not gelatinize unless previously ignited.

REMARKS.—Occurs in granite gneiss, trap, syenite, etc., as a secondary mineral derived from their alteration, and associated with other secondary minerals as datolite or the zeolites. Bergen Hill and Paterson, N. J., have furnished a few gem stones. Other localities are Farmington, Conn., the Tamarack and Quincy copper mines, Mich., Perry, Me., and Westport, N. Y.

USES.—To a limited extent has been cut as a gem.

BASIC OR SUBSILICATES.

Made a division by Dana because their constitution is not definitely settled, though probably each belongs to one of the preceding groups.

Here are described CHONDRODITE, TOURMALINE, and STAUROLITE.

CHONDRODITE.

COMPOSITION.—$H_2Mg_{19}Si_8O_{34}F_4$, or $(Mg.Fe)_{13}(Mg.F)_4(MgOH)_2(SiO_4)_5$, with some iron replacing magnesium.

GENERAL DESCRIPTION.—The chemical compound occurs as three crystallographically distinct species, chondrodite, humite, clinohumite. Chondrodite proper consists of compact brown masses or disseminated grains and yellowish-brown to red, monoclinic, pseudo orthorhombic, crystals of great complexity.

PHYSICAL CHARACTERS.—Translucent. Lustre, vitreous. Color, brown, garnet-red, light to dark yellow. Streak, white. H., 6 to 6.5. Sp. gr., 3.1 to 3.2. Brittle.

BEFORE BLOWPIPE, ETC.—Infusible, sometimes blackens and then turns white. Fused with powdered salt of phosphorus *glass* will yield fluorine. Soluble in hydrochloric acid with gelatinization.

REMARKS.—Chiefly found in crystalline limestone or with other magnesium minerals. Alters to serpentine.

TOURMALINE.—Schorl.

COMPOSITION.—$R_{18}B_2(SiO_5)_4$. R chiefly Al, K, Mn, Ca, Mg, Li.

GENERAL DESCRIPTION.—Prismatic crystals, the cross sections of which frequently show very prominently a triangular prism. Color, usually some dark smoky or muddy tint of black, brown or blue, also bright green, red, and blue, or rarely colorless. Sometimes the centre and outer shell are different colors, as red and green. Sometimes the color is different at two opposite ends. Occurs also columnar in bunches or radiating aggregates and in compact masses.

Fig. 641.

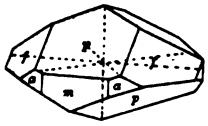


Fig. 642.

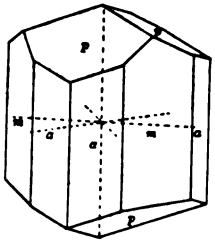
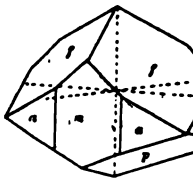


Fig. 643.



CRYSTALLIZATION.—Hexagonal. Hemimorphic class, p. Axis $c = 0.448$.

Prevailing forms: trigonal prism m, second order prism a, rhombohedron p, negative rhombohedron $f = a : \infty a : a$. Angles are: $pp = 133° 8'$; $ff = 103°$; $mp = 117° 20'$.

Optically —. Strongly dichroic, absorption very marked for vibrating parallel to the vertical axis. Double refraction r strong.

Physical Characters. H., 7 to 7.5. Sp. gr., 2.98 to 3.20.

LUSTRE, vitreous or resinous. TRANSPARENT to opaq

STREAK, white. TENACITY, brittle.

COLOR, black, brown, green, blue, red, colorless.

CLEAVAGE, difficult, parallel to R and $i-2$.

BEFORE BLOWPIPE, ETC.—Usually fuses, sometimes very e With a paste of $KHSO_4$,CaF_2 and water it yields a green f Insoluble in acids, but after strong ignition gelatinizes.

SIMILAR SPECIES.—Differs from hornblende in hardness, cry line form and absence of prismatic cleavage. Differs from g or vesuvianite in form, difficult fusion, and green flame.

REMARKS.—Occurs in crystalline rocks: granite, gneiss, mica-schists, crys limestone, etc., with many associates. By alteration it forms cookeite, lepidolit and chlorite. Tourmalines of gem value have been obtained in some quantity Paris, Auburn, and Hebron, Me., and from Riverside county, California.

USES.—Transparent, red, yellow, and green varieties are c gems. Thin plates are used to polarize light.

STAUROLITE.

COMPOSITION.—$Fe(AlO)_4(AlOH)(SiO_4)_2$, but varying. May tain Mg or Mn.

GENERAL DESCRIPTION.—Dark brown to nearly black o rhombic prisms often twinned, or in threes, crossing at 90° 120°. Surfaces bright if unaltered. Very hard.

CRYSTALLIZATION. — Orthorhombic. Axes $\dot{a} : \dot{b} : \dot{c} = 0.473 : 1 : 0.683$. Usual forms: unit prism *m*, unit dome *o* and pinacoids *b* and *c*. Frequently in twins crossed nearly at right angles, Fig. 645, or nearly at 60°, Fig. 263.

The important angles are: $mm = 129° 20'$; $co = 124° 46'$. Optically +. Axial plane the macro pinacoid. Acute bisectrix, normal to *c*.

FIG. 644.

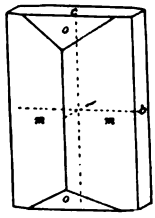
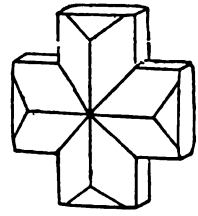


FIG. 645.



Physical Characters. H., 7 to 7.5. Sp. gr., 3.65 to 3.75.

LUSTRE, resinous or vitreous. TRANSLUCENT to opaque.

STREAK, white. TENACITY, brittle.

COLOR, dark brown, blackish-brown, gray when weathered.

CLEAVAGE, parallel to brachy pinacoid.

BEFORE BLOWPIPE, ETC.—Infusible, except when manganiferous. Partially soluble in sulphuric acid.

REMARKS.—Occurs chiefly in schistose rock with andalusite, garnet, tourmaline, cyanite, etc., but is not found in schists rich in amphibole. Abundant at Claremont, Grantham, and Lisbon, N. H., at Windham, Me., Chesterfield, Mass., Litchfield, Conn., and several other localities in New England. Also in New York, North Carolina, Georgia, and Pennsylvania.

HYDROUS SILICATES.

Compounds containing water of crystallization with certain closely related species in which the water plays the part of a base or is in doubt.

The minerals described here are:

Zeolite Division.—APOPHYLLITE, HEULANDITE, STILBITE, CHABAZITE, ANALCITE, NATROLITE.

Mica Division.—MUSCOVITE, BIOTITE, PHLOGOPITE, LEPIDOLITE, PROCHLORITE.

Serpentine and Talc Division.—SERPENTINE, TALC, SEPIOLITE.

Kaolin Division.—KAOLINITE, PYROPHYLLITE.

ZEOLITES.

The zeolites are a group of silicates, all of which are of
ondary origin and are usually found in the seams or cavi
basic igneous rocks, such as basalt or diabase, and less frec
in granite or gneiss.

They are similar to the feldspars in constituents and com
ratios, and are chiefly formed from the feldspars and from
lite, leucite, etc. Most of them fuse easily, with appeara
boiling, and all contain water of crystallization. The ha
varies from 3.5 to 5.5, and the specific gravity from 2.0

APOPHYLLITE.

COMPOSITION.—$H_{14}K_2Ca_8(SiO_3)_{16} + 9H_2O$, with replacem
fluorine.

GENERAL DESCRIPTION.—Colorless and white or pink,
crystals. Sometimes flat, square plates or approximate cub
other times pointed and square to nearly cylindrical in s
Notably pearly on base or may show in vertical direction a p
—fish eye—internal opalescence. Found occasionally in la
masses.

CRYSTALLIZATION.—Tetragonal. Axis $c = 1.252$. Usuall
binations of unit pyramid p, base c, and second order p
Angle $pp = 104°$; $cp = 119° 28'$. Prism faces vertically s

FIG. 646.

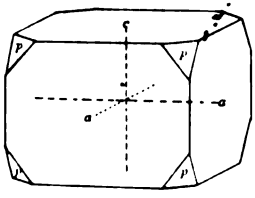


FIG. 647.

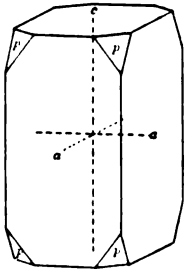
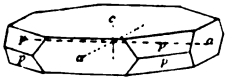


FIG. 64

FIG. 649.



Physical Characters. H., 4.5 to 5. Sp. gr., 2.3 to 2.4.
LUSTRE, vitreous or pearly. TRANSPARENT to nearly opa
STREAK, white. TENACITY, b
COLOR, colorless, white, pink or greenish. CLEAVAGE, b

BEFORE BLOWPIPE, ETC.—Exfoliates and fuses to a white enamel. In closed tube yields water. In hydrochloric acid forms flakes and lumps of jelly.

REMARKS.—Occurs in volcanic rocks and mineral veins with zeolites, datolite, pectolite, etc. It is a secondary mineral.

HEULANDITE.

COMPOSITION.—$H_4CaAl_2(SiO_3)_6 + 3H_2O$.

GENERAL DESCRIPTION.—Monoclinic crystals, with very bright, pearly cleavage surfaces. The face parallel to cleavage is also bright pearly, and is less symmetrical than the corresponding face of stilbite.

PHYSICAL CHARACTERS.—Transparent to translucent. Lustre, pearly and vitreous. Color, white, red, brown. H., 3.5–4. Sp. gr., 2.18–2.22. Brittle. Cleaves parallel to pearly face.

BEFORE BLOWPIPE, ETC.—Exfoliates and fuses easily to white enamel. In closed tube yields water. Soluble in hydrochloric acid, with residue of fine powder.

STILBITE.—Desmine.

COMPOSITION. — $H_4(Na_2.Ca)Al_2(SiO_3)_6 + 4H_2O$.

FIG. 650.

Cape Blomidon, N. S.

GENERAL DESCRIPTION.—Tabular crystals, of white, brown or red color, pearly in lustre on broad faces and frequently united by these faces in sheaf-like groups. Sometimes globular or radiated. Crystals are orthorhombic in appearance, but really complex monoclinic twins.

Physical Characters. H., 3.5 to 4. Sp. gr., 2.09 to 2.2.

LUSTRE, vitreous or pearly.
STREAK, white.
COLOR, yellow, brown, white, red.
CLEAVAGE, parallel to pearly face.
TRANSLUCENT.
TENACITY, brittle.

BEFORE BLOWPIPE, ETC.—Swells and exfoliates in fan shapes, and fuses easily to a white, opaque glass. Yields water in closed tube. Soluble in hydrochloric acid, with a pulverulent residue.

REMARKS.—Occurs with other zeolites.

CHABAZITE.

COMPOSITION.—$(Ca, Na_2)Al_2(SiO_3)_4 + 6H_2O$.

GENERAL DESCRIPTION.—Simple rhombohedral crystals, almost

cubic, also in modified forms and twins. Faces striated par to edges. Color, white, pale-red and yellow.

Physical Characters. H., 4 to 5. Sp. gr., 2.08 to 2.16.

LUSTRE, vitreous. TRANSLUCENT, transparent.

STREAK, white. TENACITY, brittle.

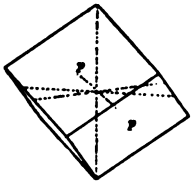
COLOR, white, red, yellow.

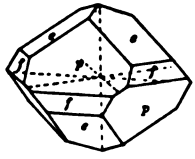
CLEAVAGE, parallel to the unit rhombohedron.

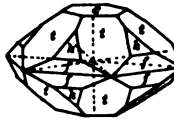
CRYSTALLIZATION.—Hexagonal. Scalenohedral class, p. Axis $c = 1.086$. Unit rhombohedron p and negative rhom hedra $e = a : \infty a : a : \frac{1}{2}c$ and $f = a : \infty a : a : 2c$ are most c mon. Angles $pp = 94° 46'$; $ee = 125° 13'$.

Optically — usually, sometimes +; interference figure confu

FIG. 651. FIG. 652. FIG. 653.







BEFORE BLOWPIPE, ETC.—Intumesces and fuses to a ne white glass containing bubbles. Yields water in closed t Soluble in hydrochloric acid, leaving flakes and lumps of jelly

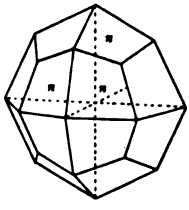
REMARKS.—Occurs generally in basaltic rocks. Found in several localit Nova Scotia. Also at Baltimore, Md.; Aussig, Bohemia; Faroer, Greenland; mond, Victoria.

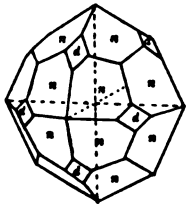
ANALCITE.

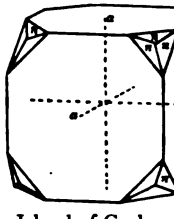
COMPOSITION.—$NaAl(SiO_3)_2 + H_2O$.

GENERAL DESCRIPTION.—Small white or colorless, tetrag

FIG. 654. FIG. 655. FIG. 656







Island of Cyclops

trisoctahedrons or modified cubes, rarely granular and com with concentric structure.

CRYSTALLIZATION.—Isometric. The tetrahexahedron $n = a : 2a : 2a$ is most frequent sometimes modified by the cube a or dodecahedron d, and in some crystals the cube predominates.

Physical Characters.—H., 5 to 5.5. Sp. gr., 2.2 to 2.29.
LUSTRE, vitreous. TRANSPARENT to opaque.
STREAK, white. TENACITY, brittle.
COLOR, white, colorless, greenish, red.

BEFORE BLOWPIPE, ETC.—Fuses easily and quietly to a clear, colorless glass. Yields water in closed tube. Gelatinizes with hydrochloric acid.

REMARKS.—A secondary mineral, usually with other zeolites.

NATROLITE.

COMPOSITION.—$Na_2Al(AlO)(SiO_3)_3 + 2H_2O$.

GENERAL DESCRIPTION.—Colorless to white, slender, nearly square prisms, with very flat pyramids. Usually in radiating and interlacing clusters and bunches. Also fibrous granular and compact.

CRYSTALLIZATION.—Orthorhombic. Axes $\breve{a} : \bar{b} : \dot{c} = 0.979 : 1 : 0.354$. mm (angle of prism) $= 91° 14'$.

FIG. 657.

Wood Cliff. N. J.

Physical Characters. H., 5 to 5.5. Sp. gr., 2.2 to 2.25.
LUSTRE, vitreous. TRANSPARENT to opaque.
STREAK, white. TENACITY, brittle.
COLOR, colorless, white, yellow, red. CLEAVAGE, prismatic.

BEFORE BLOWPIPE, ETC.—Fuses very easily to a colorless glass. In closed tube, yields water. Soluble in hydrochloric acid, with gelatinization.

SIMILAR SPECIES.—Differs from pectolite in square cross-section and fusion to a clear, colorless glass.

REMARKS.—Occurs with other zeolites and with prehnite, calcite and datolite.

THOMSONITE.

COMPOSITION.—$(Ca.Na_2)_2\ Al_4(SiO_4)_4 + 5\ H_2O$.

GENERAL DESCRIPTION.—Usually either radiating fibres or slender prismatic crystals or else spherical with fibrous structure radiating from several centres and of different colors. More rarely distinct orthorhombic prisms.

PHYSICAL CHARACTERS.—Translucent to transparent. Luster, vitreous to pearly.

Color white to colorless when pure, also greenish, reddish and yellow. Streak, w
Brittle. H., 5–55. Sp. gr., 2.3–2.4. Optically +.

BEFORE BLOWPIPE, ETC.—Yields water in closed tube. Fuses readily with bub
to a white glassy globule. Gelatinizes with hydrochloric acid.

THE MICA DIVISION.

The micas and chlorites are characterized principally by
very easy perfect basal cleavage, the monoclinic crystals with pr
angles of closely 120°, which usually appear either hexagona
orthorhombic. Cleavages show the interference figure because
acute bisectrix is nearly normal to the base. In all the speci
blow from a conical point upon a cleavage surface develops a
called percussion figure, consisting of three cracks, one paralle
the plane of symmetry, the others at definite angles to this.

The relative position of axial plane and principal line of
percussion figure and the axial angle give convenient distincti

MUSCOVITE.—Potash Mica, White Mica, Isinglas

COMPOSITION.—$H_2(K.Na)Al_3(SiO_4)_3$, with some replacemen
Mg or Fe.

GENERAL DESCRIPTION.—Disseminated scales and crys
which cleave with great ease into thin, elastic, transparent lea
Also in masses of coarse or fine scales sometimes groupe
globular and plumose forms, Fig. 659. Usually gray in colo

FIG. 658.

FIG. 659.

CRYSTALLIZATION.—Monoclinic. $\beta = 89° 54'$. *mm* (the pr
angle) = 120° 12′. Crystals usually rhombic or hexagona
section, with rough faces, and usually tapering. Cleavage is
proximately at right angles to the prism.

Optically —. Axial plane normal to *b* and nearly norma
c; that is, *normal* to the principal line of the percussion fig
Axial angle variable but large, $2E$ 50° to 70°. Pleochro
feeble. Absorption in sections normal to cleavage very strong

Physical Characters. H., 2 to 2.5. Sp. gr., 2.76 to 3.
LUSTRE, vitreous, pearly on cleavage. TRANSPARENT in laminæ.
STREAK, white. TENACITY, elastic.
COLOR, gray, brown, green, yellow, violet, red, black.
CLEAVAGE, basal, eminent.

BEFORE BLOWPIPE, ETC.—Fuses only on thin edges to a yellowish glass. Insoluble in acids.

SIMILAR SPECIES.—Differs from talc or gypsum in being elastic. Is *usually* lighter colored than biotite.

REMARKS.—Muscovite is of both igneous and secondary origin. It occurs with quartz and feldspars, in granite, gneiss and mica schist and related rocks and more or less disseminated in other rocks, and it also is found formed from cyanite, topaz, feldspars, corundum, etc. The most productive mica mines of the United States are in Mitchell, Yancey, Jackson and Macon Counties, S. C., and Groton, N. H. Other large deposits exist at Grafton, N. H.; Las Vegas and Cribbensville, N. M., and Deadwood and the Black Hills, S. D., many of which are intermittently mined. Also in Nevada, California, Colorado and Pennsylvania in quantity and quality fit for use. Large quantities of mica are annually imported from India.

USES.—As transparent material in doors of furnaces, stoves, etc. As insulating material in electrical apparatus, especially on the armatures of dynamos. As coating for spangling wall papers and such fabrics as brocade.

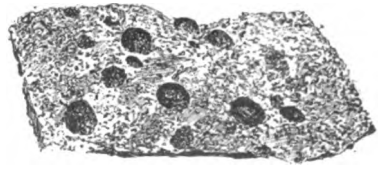
DAMOURITE.—An altered hydrous potassium mica in small scales or fibrous. Folia less elastic and of silky luster.

BIOTITE.—Black Mica, Magnesium Mica.

COMPOSITION.—An orthosilicate approximating $(H.K)_2(Mg.Fe)_2Al_2(SiO_4)_3$.

GENERAL DESCRIPTION.—Like muscovite, but usually dark green to black in color. It cleaves into thin, elastic leaves.

FIG. 660.



Prune mica, Craftsbury, Vt.]

Optically—. Axial plane usually parallel to *b*; that is *parallel* to the principal line of the percussion figure. Axial angle usually small, $2E$ varying 0 to 12°, rarely 50°. Pleochroism strong.

Physical Characters. H., 2.5 to 3. Sp. gr., 2.7 to 3.1.
LUSTRE, pearly, vitreous, submetallic. TRANSPARENT to opaque.
STREAK, white. TENACITY, tough and elastic.
COLOR, commonly black to green. CLEAVAGE, basal, eminent.

BEFORE BLOWPIPE, ETC.—Whitens and fuses on thin edges. Decomposed by boiling sulphuric acid, with separation of scales of silica.

REMARKS.—Occurrence and associates like muscovite, but is more common than muscovite in the eruptive rocks. It is found in most of the muscovite localities, and is a very common constituent of rocks and soils in the form of small scales. It alters more readily than muscovite to chlorite or to epidote, quartz and iron oxide.

PHLOGOPITE.—Amber Mica.

COMPOSITION—$R_3Mg_3Al(SiO_4)_3$, where R=H,K, MgF.

GENERAL DESCRIPTION. — Large and small, brownish-red to nearly black crystals. Usually oblong, tapering, six-sided prisms. Thin plates often show a six-rayed star by transmitted light.

Optically. — Axial plane parallel to *b*, that is *parallel* to the principal line of the percussion figure. Axial angle small, but varying in same specimen. Pleochroic in colored varieties.

FIG. 661.

Pope's Mills, N. Y.

Physical Characters. H., 2.5 to 3. Sp. gr., 2.78 to 2.85.
LUSTRE, pearly or submetallic. TRANSPARENT to translucent.
STREAK, white. TENACITY, tough and elastic.
COLOR, yellowish-brown, brownish-red, green, colorless.
CLEAVAGE, basal eminent.

BEFORE BLOWPIPE, ETC.—Whitens and fuses on thin edges. In closed tube yields water. Soluble in sulphuric acid with separation of scales of silica.

REMARKS.—Phlogopite is usually found in crystalline limestones or in serpentine. It occurs in enormous crystals in Ontario and Quebec, and in various localities through New York and New Jersey.

USES.—It is largely used in electrical work.

LEPIDOLITE.—Lithia Mica.

COMPOSITION.—$R_3Al(SiO_3)_3$. R = Li,K, NaF, etc.

GENERAL DESCRIPTION.—Scaly, granular masses of pale-pink color and gray crystals, with easy mica cleavage into elastic plates.

PHYSICAL CHARACTERS.—Translucent. Lustre, pearly. Color, rose, violet, lilac, gray, white. Streak, white. H., 2.5 to 4. Sp. gr., 2.8 to 2.9. Sectile. Cleavage, basal.

BEFORE BLOWPIPE, ETC.—Fuses easily to white glass. Colors flame purple-red. Partially soluble in hydrochloric acid.

CLINOCHLORE.—Ripidolite.

COMPOSITION.—$H_8Mg_5Al_2Si_3O_{18}$.

FIG. 662.

GENERAL DESCRIPTION.—Green, white and rose-red crystals with cleavage like mica, the cleavage plates however being only slightly elastic. Also masses made up of coarse or fine scales and earthy.

PHYSICAL CHARACTERS.—Transparent to translucent. Lustre, vitreous to pearly. Color, green to red. Streak, light green. H., 2–2.5. Sp. gr., 2.65–2.75. Cleavage perfect, micaceous. Laminæ flexible but not elastic. Optically usually +. Pleochroic. Axial angle 20° to 90°.

BEFORE BLOWPIPE, ETC.—When highly heated yields much water in closed tube Fuses only on the edges to a yellow enamel. Only slightly affected by HCl.

REMARKS.—Found at West Chester and Texas, Pa.; Brewsters, N. Y., and many foreign localities.

PROCHLORITE.

FIG. 663.

COMPOSITION.—$H_{40}(Fe.Mg)_{23}Al_{14}Si_{13}O_{90}$.

GENERAL DESCRIPTION.—Dark-green masses, composed of coarse to very fine scales. Also tabular and curiously twisted six-sided crystals, which easily cleave into thin plates which are not elastic. Also frequently distributed as a pigment in other minerals. Optically +. Axial angle small, $2E = 0°$ to $30°$. Pleochroism distinct.

Physical Characters. H., 1 to 2. Sp. gr., 2.78 to 2.96.

LUSTRE, feebly pearly. TRANSLUCENT to opaque.
STREAK, white or greenish. TENACITY, flexible, non-elastic.
COLOR, grass-green to blackish-green.
CLEAVAGE, basal. FEEL, slightly soapy.

BEFORE BLOWPIPE, ETC.—Whitens and then fuses to a nearly black magnetic glass. In closed tube yields water. Soluble in sulphuric acid.

REMARKS.—Formed by decomposition of mica and aluminous varieties of amphibole, garnet, pyroxene, etc., and occasionally found in crystalline schists and serpentines.

Delessite, a dark-green massive mineral of scaly or short fibrous appearance. H., 2.5. Sp. gr., 2.9, which yields water in closed tube and is decomposed by HCl with separation of silica. Found in cavities of amygdaloidal eruptive rocks.

SERPENTINE AND TALC DIVISION.

SERPENTINE.

COMPOSITION.—$H_4Mg_3Si_2O_9$, with replacement by Fe.

GENERAL DESCRIPTION.—Fine granular masses or microscopically fibrous. Also foliated and coarse or fine fibrous. Color, green, yellow or black, and usually of several tints dotted, striped and clouded. Very feeble, somewhat greasy lustre and greasy feel. Crystals unknown.

Physical Characters. H., 2.5 to 4., Sp. gr., 2.5 to 2.65.

LUSTRE, greasy, waxy or silky. TRANSLUCENT to opaque.
STREAK, white. TENACITY, brittle.
COLOR, green to yellow, brown, red, black, variegated.

BEFORE BLOWPIPE, ETC.—Fuses on edges. In closed tube, yields water. In cobalt solution becomes pink. Soluble in hydrochloric acid, with a residue.

REMARKS.—A secondary mineral formed from chrysolite, amphibole, pyroxene, enstatite, etc. It is associated with these and with magnetite, garnierite, chromite, dolomite, etc. Serpentine asbestus is not produced in the United States, but large amounts are annually imported from the Thetford and Coleraine mines of Quebec. Massive serpentine, or Verd Antique marble, is quarried at Milford, Conn.

USES.—It takes a fine polish, and is used for ornamental work, as table-tops, mantels, etc. The fibrous variety, chrysotile, is used as asbestus.

TALC.—Steatite, Soapstone.

COMPOSITION.—$H_2Mg_3(SiO_3)_4$.

GENERAL DESCRIPTION.—A soft, soapy material, occurring foliated, massive, and fibrous, with somewhat varying hardness. Usually white, greenish or gray in color. Crystals almost unknown.

Physical Characters. H., 1. Sp. gr., 2.55 to 2.87.

LUSTRE, pearly or wax-like. TRANSLUCENT.
STREAK, white. TENACITY, sectile.
COLOR, white, greenish, gray, brown, red.
CLEAVAGE, into non-elastic plates. FEEL, greasy.

BEFORE BLOWPIPE, ETC.—Splits and fuses on thin edges to white enamel. With cobalt solution, becomes pale pink. Insoluble in acid.

VARIETIES.

Foliated Talc.—H = 1. White or green in color. Cleavable into non-elastic plates.

Soapstone or Steatite.—Coarse or fine, gray to green, granular masses. H., 1.5 to 2.5.

French Chalk.—Soft, compact masses, which will mark cloth.

Agolite.—Fibrous masses of H. 3 to 4.

Rensselaerite.—Wax-like masses. H., 3 to 4. Pseudomorphous after pyroxene.

SIMILAR SPECIES.—Softer than micas or brucite or gypsum. Further differentiated by greater infusibility, greasy feel, and the flesh-color obtained with cobalt solution.

REMARKS.—Talc is an alteration product of pyroxene, amphibole, muscovite, enstatite, etc., and occurs with dolomite, serpentine, magnesite, tourmaline, etc. An immense deposit at Gouverneur, N. Y., is mined, and the total output is ground for use in paper-making, etc. Large soapstone quarries are worked at Francestown, N. H. Chester, Saxon's River, Cambridgeport and Perkinsville, Vt., Cooptown, Md., and Webster, N. C. Massachusetts, New Jersey, Pennsylvania, Virginia and Georgia are also producing States.

USES.—Soapstone is cut in slabs for hearths, linings of stoves, sinks and other articles of refractory nature. It is ground and moulded into gas-tips, and used as a preparation for blackboards and as a fine quality of tinted plastering. Agolite is used to mix with wood pulp in paper manufacture. Talc is used in soap, as a dressing for fine skin and leather, as a lubricant and as pencils, tailors' chalk, etc.

SEPIOLITE.—Meerschaum.

COMPOSITION.—$H_4Mg_2Si_3O_{10}$.

GENERAL DESCRIPTION.—Soft compact white, earthy to clay-like masses, of very light weight. Rarely fibrous.

Physical Characters. H., 2 to 2.5. Sp. gr., 1 to 2.

LUSTRE, dull.	OPAQUE.
STREAK, white.	TENACITY, brittle.
COLOR, white, gray, rarely bluish-green.	FEEL, smooth.

BEFORE BLOWPIPE, ETC.—Blackens, yields odor of burning and fuses on thin edges. In closed tube yields water. With cobalt solution becomes pink. In hydrochloric acid gelatinizes.

SIMILAR SPECIES.—Resembles chalk, kaolinite, etc., but is characterized by lightness and gelatinization with acids.

REMARKS.—Possibly formed from Magnesite. The name "meerschaum" refers to the fact that it will float on water when dry. Most of the material used for pipes is obtained from Turkey. It occurs in large amount in Spain, and in smaller quantities in Greece, Morocco and Moravia. There are no productive American localities.

USES.—As material for costly tobacco pipes. In Spain it is a building stone. In Algeria it is used as a soap.

KAOLINITE.—Kaolin, China Clay.

COMPOSITION. $H_4Al_2Si_2O_9$, with more or less iron, silica, and organic matter.

GENERAL DESCRIPTION.—Compact and clay-like or loose and mealy masses of pure white, yellow, brown, red and blue color. Also in white, scale-like crystals, with the lustre of satin. Usually unctuous and plastic.

Physical Characters. H., 2 to 2.5. Sp. gr., 2.6 to 2.63.
LUSTRE, dull or pearly. OPAQUE or translucent.
STREAK, white or yellowish. TENACITY, brittle.
COLOR, white, yellow, brown, red and blue.

BEFORE BLOWPIPE, ETC.—Infusible. Yields water in closed tube. With cobalt solution, becomes deep blue. Decomposed by sulphuric acid, but insoluble in nitric or hydrochloric acids.

SIMILAR SPECIES.—It is not harsh like infusorial earth and is softer than bauxite.

REMARKS.—Kaolinite is formed by alteration of feldspars and other silicates. Carbonated waters remove the basic oxides and part of the silica. Its associates are feldspars, corundum, diaspore, topaz, etc. In the United States kaolinite is mined at Okahumka, Lake County, Florida, at Sylva, Dilsboro and Webster, N. C., and at several places in New Castle County, Del., and Chester and Delaware Counties, Pa. Kaolin of poorer quality is obtained in Ohio and New Jersey, and many other deposits are known throughout the Atlantic States.

USES.—It is the chief constituent of porcelain, chinaware, ornamental tiles, etc.

PYROPHYLLITE.—Pencil Stone.

COMPOSITION.—$HAl(SiO_3)_2$.

GENERAL DESCRIPTION.—Radiated foliæ or fibres and compact masses of soapy feeling and soft and smooth like talc.

PHYSICAL CHARACTERS.—Translucent to opaque. Lustre, pearly or dull. Color, white, greenish, brownish or yellow. Streak, white. H., 1 to 2. Sp. gr., 2.8 to 2.9. Flexible.

BEFORE BLOWPIPE, ETC.—Whitens and fuses on the edges, and often swells and spreads like a fan. In closed tube yields water. Partially soluble in sulphuric acid.

REMARKS.—Occurs in large beds and as gangue of cyanite.

USES.—Extensively manufactured into slate pencils.

TITANO-SILICATES.

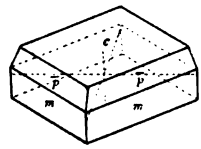
TITANITE.—Sphene.

COMPOSITION.—$CaSiTiO_5$.

GENERAL DESCRIPTION.—Brown, green or yellow, wedge-shaped or tabular monoclinic crystals, with adamantine or resinous lustre. Also compact, massive. Rarely lamellar.

CRYSTALLIZATION.—Monoclinic. $\beta=60°\ 17'$. Axes $\dot{a} : \bar{b} : \dot{c} = 0.755 : 1 : 0.854$. Crystals very varied. Most common forms: pinacoids c and a, unit prism m, negative unit pyramid $\bar{p}$, domes $x = \dot{a} : \infty\ \bar{b} : \frac{1}{2}\ c$ and $s = \infty\ \dot{a} : \bar{b} : 2c$, and the pyramid $l = \dot{a} : \bar{b} : \frac{1}{2}\ c$. Angles are: $mm = 113°\ 31'$; $pp = 136°\ 11'$; $ll = 133°\ 53'$.

FIG. 664.



Diana, N. Y.

Optically +. Axial plane the plane of symmetry. Very large dispersion producing peculiar interference figure with many lemniscates and colored hyperbolæ.

Physical Characters. H., 5 to 5.5. Sp. gr., 3.4 to 3.56.

LUSTRE, adamantine or resinous. TRANSPARENT to opaque.

STREAK, white. TENACITY, brittle.

COLOR, brown to black, yellow, green, rarely rose-red.

CLEAVAGE, prismatic easily, pyramidal less easily.

BEFORE BLOWPIPE, ETC.—Fuses, with intumescence, to a dark glass, sometimes becoming yellow before fusion. In salt of phosphorus after reduction, the bead is violet. Partly soluble in hydrochloric acid, completely so in sulphuric acid.

REMARKS.—Occurs both as original and secondary mineral derived from alteration of menaccanite, brookite, etc. Its associates are pyroxene, amphibole, feldspars, zircon, iron ores, apatite, etc. Good gem stones have been found at Brewsters, N. Y.; Bridgewater, Pa., and Magnet Cove, Ark.

USES.—As a gem.

PART IV.

DETERMINATIVE MINERALOGY.

CHAPTER XXXVI.

TABLES FOR RAPID DETERMINATION OF THE COMMON MINERALS.

In the tables which follow, the minerals are divided first into minerals of metallic lustre and minerals of non-metallic lustre. The minerals of metallic lustre are divided into forty-eight groups by eight horizontal divisions based on color and hardness and six vertical divisions based on the effect of the blowpipe flame on charcoal.

From the minerals of non-metallic lustre a division, *A*, of, minerals possessing a taste, that is, soluble in water, is set aside. The non-metallic minerals without taste, as Division B and C, are then divided into forty-four groups, the action of hydrochloric acid given in each four horizontal divisions, and the action upon charcoal, in *B*, and in the platinum forceps, in *C*, giving the vertical divisions.

The species in each group are printed in heavy type or ordinary type, according to their importance. The symbols, I., T., H., O., M., Tri. before each name designate the system of crystallization. The formula following is expected to suggest confirmatory blowpipe tests and the lines of fine type to suggest distinctive tests or characters. H signifies hardness, G, specific gravity, S. Ph., salt of phosphorus. The page reference to the complete description of the species is also given.

For accurate results these precautions must be taken :

1. All tests should be made upon homogeneous material, preferably crystalline, as the tests may be unreliable if the material is impure, *unless the effect of the impurity upon the test is known.*

2. The classifying tests must be *decided*, and, if weak, should be attributed either to improper manipulation or to the presence of some accidental impurity.

3. The lustre must be observed on a fresh fracture.

4. The determination must be confirmed by reference to the description of the species, and, when possible, by comparison with known specimens.

5. When the test is very close to a line of division it is better to look for the mineral upon both sides of the line.

If, as may happen, a specimen belongs to a rare species not included in the scheme, it will not yield tests corresponding to any species therein and more elaborate tables will be needed.

LUSTRE.

		Gives Garlic Od	ves Non-Magnetic L but no Coating or Garlic Odor.	Not Previously Included.
The Color is Silver-White, Tin-White or Gray.	Distinctly Scratched by Calcite.		eyerite, p. 281, $(Ag,Cu)_2S$ am, p. 280, AgHg copper.	—. Mercury, p. 276, Hg Fluid globules. Entirely volatilized.
	Scratched by a Knife (distinctly).	H. Arsenic, p. 255, As Brittle. Blue flame. H. Antimony, p. 258, Sb Thick fumes. Green fla I. **Tetrahedrite**, p. 269, See opposite.	, p. 279, Ag e. Silver streak. o 11. ium, p. 290, Pt. nd scales. G=14 to 19	
	Not Distinctly Scratched by a Knife.	**In closed tube** O. Leucopyrite p. 202, Fe Black sublimate. I. Gersdorffite, p. 224, Ni Yellowish-brown sublim I. **Cobaltite**, p. 220, CoA I. **Smaltite**, p. 221, (Co, Black sublimate. I. Chloanthite, p. 225, (N Black sublimate. O. **Arsenopyrite**, p. 20 Red sublimate, then bla	mine, p. 290, (Ir,Os) ins.	
The Color is Black or Nearly Black.	Distinctly Scratched by Calcite.		itite, p. 280, Ag_2S Residue of silver. rite, p. 271, CuO scales or earthy masses.	H. **Graphite**, p. 341, C Soapy feel. Shining streak. O. **Pyrolusite**, p. 216, MnO_2 Radiating or compact. Black streak.
	Dist'ly Scr'd by a Knife.	O. **Enargite**, p. 268, Cu_3 Columnar. I. Tennantite, p. 269, Cu Granular.	cocite, p. 266, Cu_2S Residue of copper.	I. Alabandite, p. 214, MnS Cubic cleavage. Green streak. O. **Manganite**, p. 216, MnO(OH) Prismatic. Dark-brown streak.
	Not Distinctly Scratched by a Knife.			I. Perovskite, p. 317, $CaTiO_3$ Violet bead S.Ph. in R.F. O. Columbite, p. 212. $Fe(CbO_3)_2$ Brilliant lustre. G=5.3 to 7.3 I. **Uraninite**, p. 260, U,Pb, Th, etc. Botryoidal. Green S.Ph. in R.F. —. **Psilomelane**, p. 217, H_4MnO_5 Botryoidal. Brownish-black streak T. Hausmannite, p. 215, Mn_3O_4 Twin pyramids. Chestnut-brown streak. T. **Braunite**, $Mn_2O_3.MnSiO_3$ Black streak. Gelatinizes, p. 215. T. **Rutile**, p. 237, TiO_2 Violet bead S.Ph. in R.F. O. Brookite, p. 238, TiO_2 Violet bead S.Ph. in R.F.
Yellow, Red, Bronze.	Distinctly Scratched by a Knife.	H. **Niccolite**, p. 224, Ni Color, copper-red. Stre	p. 287, (Au,Ag) streak. Malleable. er, p. 265, Cu streak. Malleable. ite, p. 270, Cu_2O ish-red streak. Brittle.	
	Not S'd by Knife.			

RE.

NAME.	REMARKS.
Tri. **Sassolite**, p. 331, H_3BO_3	White pearly scales, smooth feel.
M. Mirabilite, p. 296, $Na_2SO_4+10H_2O$	White efflorescent crusts.
O. Mascagnite, p. 297, $(NH_4)_2SO_4$	Gray mealy crusts and stalactites.
O. Epsomite, p. 318, $MgSO_4+7H_2O$	White massive or silky fibers.
H. Aphthitalite, p. 291, $(K,Na)_2SO_4$	Delicate crystals on lava, or crusts.
M. **Borax**, p. 332, $Na_2B_4O_7+10H_2O$	White crystals resembling those of pyroxene, or crusts.
M. Trona, p. 296, $Na_2CO_3.NaHCO_3+2$	White glistening crusts or beds.
I. Arsenolite, p. 257, As_2O_3	White capillary or incrusting.
M. Alunogen, p. 327, $Al_2(SO_4)_3+18H_2$	White silky fibers or crusts.
M. Melanterite, p. 209, $FeSO_4.7H_2O$	Pale green efflorescence on sulphide of iron.
O. Goslarite, p. 229, $ZnSO_4+7H_2O$	White alteration on or near sphalerite.
I. **Kalinite**, p. 292, $KAl(SO_4)_2+12H_2$	White efflorescence on clay minerals.
Tri. Chalcanthite, p. 272, $CuSO_4+5H_2$	Blue crystals or masses.
M. **Copiapite**, p. 208, $Fe_2Fe(OH)_2(SO$	Yellow scales or granular masses.
H. **Soda Nitre**, p. 296, $NaNO_3$	Deliquescent crusts.
I. Sal Ammoniac, p. 297, NH_4Cl	White crystals or incrusting.
O. **Nitre**, p. 292, KNO_3	Acicular crystals or tufts. Not altered by exposure.
I. Sylvite, p. 290, KCl	Colorless cubes or white masses.
O. Thenardite, p. 295, Na_2SO_4	White crossed and simple crystals.
I. **Halite**, p. 294, NaCl	White or brown cubes or masses.
M. Glauberite, p. 295, $Na_2SO_4.CaSO_4$	Gray tabular crystals. Efflorescence on long exposure.
M. **Kainite**, p. 292, $MgSO_4.KCl+3H_2O$	White to red granular masses.

cing flame, Yields:

The Mineral, in finest Powder, Boiled with Hydrochloric Acid.

	ARSENICAL	T PREVIOUSLY LUDED.	MAGNETIC RESIDUE BUT IS NON-VOLATILE.
Is Dissolved with Effervescence.		33, CdS n coal.	H. **Siderite**, p. 210, $FeCO_3$ Sp. Gr. 3.8 to 3.9. Brown. H. Ankerite, p. 316, $(Ca,Mg,Fe)CO_3$ Sp. Gr. 2.9 to 3.1. Gray to brown. H. **Rhodochrosite**, p. 218, $MnCO_3$ Sp. Gr. 3.3 to 3.6. Pink to red. —. Zaratite, p. 225, $Ni_2CO_3.(OH)_2+4H_2O$ Emerald green vitreous crust.
Dis'l'd Forms Jelly.			M. Allanite, p. 380, $R''_2R_3(SiO_4)_3$ O. Fayalite, p. 372, $FeSiO_4$ Minute tabular crystals or massive.
Is Dissolved without Effervescence or Formation of Jelly.	**Magnetic R** O. Scorodite, p. 210, FeA Pale green or brown. I. Pharmacosiderite, p. Small cubes, green to y M. Annabergite, p. 225, Apple green crusts or fi M. Erythrite, p. 221, Co Crimson fibers and pris **Non-Magnetic** H. Mimetite, p. 247, Pb_4 Prisms or globular gro O. Olivenite, p. 273, Cu Olive green to brown cr M. Pharmacolite, p. 310, White or pink silky fib		M. Triplite, p. 218, $(Fe,Mn)_2FPO_4$ Brown resinous masses. O. Triphylite, p. 299, $Li(Fe,Mn)PO_4$ Red flame. Rectangular cleavage. O. Hypersthene, p. 358, $(Mg,Fe)SiO_3$ Foliated, metalloidal. M. Vivianite, p. 209, $Fe_3(PO_4)_2+8H_2O$ Blue color and streak. **Streak yellow to brown.** —. Limonite, p. 207, $Fe_2O_3.Fe_2(OH)_6$ Earthy to compact or fibrous. O. Goethite, p. 207, $FeO(OH)$ Needles, scales and velvet crusts. **Streak Red.** Turgite, p. 207, $Fe_4O_5(OH)_2$ In closed tube flies to pieces. H. **Hematite**, p. 204, Fe_2O_3 In closed tube unchanged.
Is Insoluble or Nearly Insoluble.	H. **Proustite**, p. 281, A_3S Color and streak scarle O. **Orpiment**, p. 256, A_2 Color and streak lemon M. **Realgar**, p. 256, As Streak orange red, colo	me and odor SO_2 , HgS volatilized. ass with $KHSO_4$ 284, AgCl white cold. Ag(ClBr) AgBr low cold. AgI e dark red hot.	M. **Biotite**, p. 388. Black micaceous. M. Acmite, p. 360, $NaFe(SiO_3)_2$ Colors flame yellow. M. **Pyroxenes**, p. 358, rich in iron. Angle of prism 87°10'. M. **Amphiboles**, p. 363, rich in iron. Angle of prism 124°11'. I. **Garnets**, p. 369, Andradite, Almandite. M. **Epidote**, $Ca_2(Al,Fe)_3(AlOH)(SiO_4)_3$ Green, grains, fibers or crystals. P. 379.

RE.

C. If the Mineral is ... he Forceps at Tip of Blue Flame. 3

The Mineral in Finest Powder, Boiled with Hydrochloric Acid.

	Fuses Easily to a White or Enamel.	...le but in Powder Made ...lue by Cobalt Solution.	Infusible, not Included Previously.
Is Dissolved with Effervescence.	O. **Witherite**, p. 299, $BaCO_3$. Colors flame yellowish gree... M. Gaylussite, $CaNa_2(CO_3)_2$. Intense yellow flame. P. 2... H. Cancrinite, $R(Na_2CO_3)(S...$ Forms a jelly on heating. ...		H. **Magnesite**, p. 319, $MgCO_3$. White chalk-like masses. H. **Rhodochrosite**, p. 218, $MnCO_3$. Pink to red. **Flame is colored red by:** H. **Calcite**, p. 311, $CaCO_3$. G. 2.71. Rhombohedral cleavage. O. **Aragonite**, p. 310, $CaCO_3$. G—2.95. H. **Dolomite**, p. 314, $(CaMg)CO_3$. Slow effervescence of lumps.
Is Dissolved with Formation of Jelly.	M. Pectolite, p. 362, $HNa_2Ca...$ Radiating splintery fibers, O. Thomsonite, $(Na_2Ca)Al_2S...$ P. 387. M. **Wollastonite**, p. 361, $Ca...$ T. **Apophyllite**, p. 384, $H_{14}K_2Ca_8(SiO_3)_...$ Swells colors flame violet. H. **Chabazite**, p. 385, $(Ca,Na_2)Al_2(SiO_3)_4...$ Intumesces. Nearly cubic. I. Hauÿnite, p. 368, $3(Na_2Ca)Al_2SO_4...$ Rounded grains. Sulphur ... I. Lazurite, p. 369, $Na_4(NaS_2Al)Al_2...$ Intumesces. Deep blue col...		T. Thorite, p. 240, $ThSiO_4$. H—5. Orange to brown. H. Dioptase, p. 275, H_2CuSiO_4. H—5. Emerald green. O. **Chrysolite**, p. 371, $(Mg,Fe)_2SiO_4$. H—7. Olive to gray-green. M. Chondrodite, $H_2Mg_5Si_2O_8F_2$. H—6.5. Brown to yellow. P. 381.
Is Dissolved Without Effervescence or Formation of Jelly.	M. **Cryolite**, p. 323, $AlNa_3F...$ Yellow flame. H=2.5. T. **Wernerite**, Ca,Na,Al,Si... Yellow flame. H=5 to 6. I. **Fluorite**, p. 304, CaF_2. Red flame. Cubic, fluoresce... M. **Gypsum**, p. 306, $CaSO_4+...$ Pale red flame. Water test. O. **Anhydrite**, p. 305, $CaSO...$ Pale red flame. H=3. I. Boracite, p. 334, $Mg_7Cl_2B_...$ Green flame. Pink by Co so... M. **Stilbite**, $H_4R_2Al_2(SiO_3)_6...$ Sheaf-like. Swells with hea... P. 385. M. Heulandite, p. 385, $H_4CaAl_2(SiO_3)_6...$ Lozenge-shaped. Swells wit... O. **Prehnite**, $H_2Ca_2Al_2(SiO...$ Usually green. H=6 to 6.5. Colemanite	...nite, p. 327, $Al_2SO_{11}.9H_2O$ White chalky masses. ...te, p. 326, $Al_2O(OH)_4$ ...like clay. ...lite, p. 329. $Al_6(OH)_6(PO_4)_4+9H_2O$ ...nd hemispheres of radiat... ...tals. ...ois, $Al_2(OH)_3PO_4.H_2O$ ... to green with lustre of wax. ...e, p. 357, $KAl(SiO_3)_2$ ...risotachedrons. White or ...color.	M. Monazite, p. 240, $(Ce,La.Di)(PO^4)$ Resinous brown crystals or yellow grains. H. **Brucite**, p. 318, $Mg(OH)_2$ Foliated or fibrous. Pink with Co solution. —. Wad, p. 217, Mn oxides. Dull earthy brown to black. —. **Garnierite**, p. 226, $H_2(Ni,Mg)SiO_4+H_2O$ Deep green to pale green. Soft and friable. —. **Chrysocolla**, $CuSiO_3+2H_2O$ Green to sky-blue with waxy lustre. P. 274.
Is Insoluble or Nearly Insoluble.	Tri. **Albite**, p. 355, $NaAlSi_3...$ Yellow flame. H=6. Tri. **Oligoclase**, p. 355, $n(Na_2Al_2Si_2O_8).(CaAl_2...$ Yellow flame. H=6. M. Petalite, p. 352, $AlLi(Si_2O_4...$ Red flame. Phosphor... G=2.4 + O. **Celestite**, p. 300, $SrSO_4$ Red flame. G=3.9+ M. Lepidolite, p. 390, $R_2Al(S...$ Red flame. Micaceous. O. **Barite**, p. 298, $BaSO_4$ Green flame. G=4.3. O. Zoisite, $Ca_2(AlOH)Al_2(SiO...$ Columnar. No flame. P. 3... H. **Tourmaline**, $R_{13}B_2(SiO...$ P. 381. M. **Pyroxene**, p. 358, $RSiO_3$ M. **Amphibole**, p. 363, $RSiO...$ H. **Beryl**, p. 364, $Be_3Al_2(SiO...$	...hite, p. 394, $H_4Al_2Si_2O_9$ ...5. Soapy feel. ...ite, p. 326, $Al(OH)_3$ ...3.5. Clay odor. ...e, $K(AlO_2)(SO_4)_2+3H_2O$ ...4. Small white cuboids. ...e, p.329, $RAl_3(OH)_2(PO_4)_2$ ... Acute blue pyramids. ...ite, p. 366, $(AlO)_2SiO_3$ ...ue bladed crystals. ...ite, p. 377, $Al(AlO)SiO_4$ Gray to brown crystals ...s. ...e, p. 326, AlO(OH) ...early, pink to brown. ...site, p. 377, $Al(AlO)SiO_4$ ...5. Square prisms. ...ite, p. 372, Be_2SiO_4 ...8. Resembles quartz. p. 319, $MgAl_2O_4$ ...tahedrons. p. 375, $Al(Al(OF_2)SiO_4$ ...sms with basal cleavage. ...beryl, p. 330, $BeAl_2O_4$ ...abular, yellow or green. ...dum, p. 324, Al_2O_3 ...=4. Adamantine.	T. Octahedrite, p. 238, TiO_2 Brown or blue pyramids. Adamantine. T. **Rutile**, p. 237, TiO_2 Red to black. Adamantine prismatic, often needles. G—4.2. T. **Cassiterite**, p. 235, SnO_2 Brownish-black. Adamantine, pyramidal and prismatic. G—6.8 to 7.1. H. **Quartz**, p. 346, SiO_2 H—7. G—2.65. Very varied. H. Tridymite, p. 350, SiO_2 Minute tabular crystals. —. **Opal**, p. 350, SiO_2nH_2O H—5.5 to 6.5. G—2.1 to 2.2. Fracture conchoidal. T. **Zircon**, p. 374, $ZrSiO_4$ H—7.5. Pyramid and prism. O. **Staurolite**, p. 382, $Fe(AlO)_4(AlOH)(SiO_4)$ H—7.5. Prisms. Usually twinned. H. **Tourmaline**, $B_{13}B_2(SiO_3)_4$ H—7.5. Hemimorphic. P. 381. I. **Garnet**, p. 369, Uvarovite, $Ca_3Cr_2(SiO_4)_3$ H—7.5. Emerald green crystals. I. **Diamond**, p. 240, C. H—10. Adamantine. G—3.51.

TABLE OF ATOMIC WEIGHTS.

ACCORDING TO CLARKE (H=1).

Element.	Symbol.	At. Wt.	Element.	Symbol.	At. Wt.
Aluminum	Al.	26.91	Mercury	Hg	198.49
Antimony	Sb	119.52	Molybdenum	Mo	95.26
Argon	A	?	Neodymium	Nd	139.70
Arsenic	As	74.44	Nickel	Ni	58.24
Barium	Ba	136.39	Nitrogen	N	13.93
Bismuth	Bi	206.54	Osmium	O	189.55
Boron	B	10.86	Oxygen	O	15.88
Bromine	Br	79.34	Palladium	Pd	105.56
Cadmium	Cd	111.10	Phosphorus	P	30.79
Calcium	Ca	39.76	Platinum	Pt	193.41
Carbon	C	11.91	Potassium	K	38.82
Cerium	Ce	138.30	Praseodymium	Pr	142.50
Cesium	Cs	131 89	Rhodium	Rh	102.23
Chlorine	Cl	35.18	Rubidium	Rb	84.78
Chromium	Ch	51.74	Ruthenium	Ru	100.91
Cobalt	Co	58.55	Samarium	Sm	149.13
Columbium	Cb	93.02	Scandium	Sc	43.78
Copper	Cu	63.12	Selenium	Se	78.42
Erbium	Er	165.06	Silicon	Si	28.18
Fluorine	F	18.91	Silver	Ag	107.11
Gadolinium	Gd	155.57	Sodium	Na	22.88
Gallium	Ga	69.38	Strontium	Sr	86.95
Germanium	Ge	71.93	Sulphur	S	31.83
Glucinum / Berylium	Gl / Be	9.01	Tantalium	Ta	181.45
			Tellurium	Te	126.52
Gold	Au	195.74	Terbium	Tb	158.80
Helium	He	?	Thallium	Tl	202.61
Hydrogen	H	1.00	Thorium	Th	230.87
Indium	In	112.99	Thulium	Tu	169.40
Iodine	I	125.89	Tin	Sn	118.15
Iridium	Ir	191.66	Titanium	Ti	47.79
Iron	Fe	55.60	Tungsten	W	183.43
Lanthanum	La	137.59	Uranium	U	237.77
Lead	Pb	205.36	Vanadium	V	50.99
Lithium	Li	6.97	Ytterbium	Yt	171.88
Magnesium	Mg	24.10	Yttrium	Y	88.35
Manganese	Mn	54.57	Zinc	Zn	64.91
			Zirconium	Zr	89.72

GENERAL INDEX.

Absorption of light, 177
in doubly refracting crystals, 178
in isometric crystals, 177
in optically biaxial crystals, 179
in optically uniaxial crystals, 178
Acicular, 144
Acid potassium sulphate, reactions with, 108
Acids, uses of in blowpipe work, 107
results obtained with, 107
Adamantine lustre, 154
Aluminates, 190
Aluminum, minerals of, 321
uses and extraction, 321, 322
summary of tests, 110
see also, 99, 108, 130, 134
Ammonium, minerals of, 297
summary of tests, 110
Amorphous, 142
Angle between optic axes, determination, 175
Angle of least deviation, 164
Antimonides, 189
Antimony, minerals of, 257
uses and extraction, 257
summary of tests, 110
see also, 97, 98, 102, 107, 125, 128
Apparatus, 86
Arborescent, 144
Arsenates, 191
Arsenic, minerals of, 255
uses and extraction, 255
summary of tests, 111
see also, 97, 98, 99, 102, 107, 125, 133
Arsenides, 189
Asterism, 155
Atomic weights, table of, 399
Axes, crystallographic, 5
Axes, interchangeable or equivalent, 6
of the six systems, 6
selection of in each system, 7
Axial angle, measurement, 175
Axial cross, construction, 76

Barium, minerals of, 298
uses of, 298
summary of tests, 112
see also, 99, 130, 133, 135
Basal pinacoid, see pinacoid
Basic silicates, 381
Beads, how to make, 88
Bead tests, 103
Beryl formula, calculation, 192
Berzelius lamp, 85
Biaxial crystals,
absorption, pleochroism, 179
optical characters, 171
Bismuth, minerals of, 251
uses and extraction, 252
summary of tests, 112
see also, 97, 98, 99, 102, 107, 127, 128
Bismuth-flux, composition, 98
reactions with, 98
Bladed, 143
Blast, method of blowing, 87
Blowpipe analysis, scheme for, 125
Blowpipe, description of the, 83
care of, 83
Blowpipe lamp, 84, 85
Boracic acid, uses, 109
Boracic acid flux, reactions with, 109
Borates, 190
Borax, action of as flux, 103
reactions with, 104, 105
how to make bead, 88
Boron, minerals of, and their uses, 331
summary of tests, 112
see also, 132, 133
Botryoidal, 143
Brachy dome, see dome
pinacoid, see pinacoid
pyramid, see pyramid

Braun's solution, 151
Brittle, 146
Bromides, 189
Bromine, summary of tests, 112
see also, 101, 108, 131
Bunsen burner as lamp, 84

Cadmium, mineral, 233
use and extraction, 233
summary of tests, 113
see also, 99, 102, 107, 126
Cæsium, tests for, 95
Calcium, minerals and their uses, 303
summary of tests, 113
see also, 95, 99, 130, 133, 135
Capillary, 144
Carbon minerals and their uses, 338
Carbonates, 189
Carbon dioxide, summary of tests, 113
see also, 101, 108, 132, 133
Characters of minerals, 137, *et seq.*
Charcoal, method of using, 95
reactions obtained on, 97, 98
forms used, 85
Chart, spectroscopic, 94
Chemical composition of minerals, 187
Chlorides, 189
Chlorine, summary of tes's, 113
see also, 108, 113, 131
Chromates, 190
Chromium, summary of tests, 113
see also, 102, 105, 129
from chromite, 196
Circularly polarizing uniaxial crystals, 169
Cleavage, 146
Clino dome, see dome
pinacoid, see pinacoid
prism, see prism
pyramid, see pyramid
Closed tubes, uses of, 101
reactions in, 101
Cobalt, minerals of, 219
uses of, 219
extraction of, 219
summary of tests, 114
see also, 99, 105, 106, 107, 109, 126, 130
Cobalt solution, reaction with, 108
Color, terms used, 155
Coloration of flame, 91
Columbates, 191
Columnar, 142
Composition of minerals, 188
Conductivity of minerals, 184
Copper, minerals of, 263
uses and extraction, 263, 264
summary of tests, 114
see also, 99, 102, 105, 106, 109, 127, 130
Crystal expansion, 181
forms, 8
habit, 9
projection, 76–81
Crystalline aggregates, 142
Crystalline structure, explanation of, 1
Crystals, classification, 6
circularly polarizing, 169
definition, 1
determination of optical characters, 168, 174
electrical characters, 183
laws of, 2
magnetic characters, 183
optical characteristics, 164, *et seq.*
positive and negative, 166, 172
thermal characters, 180
Crystals of minerals, 138
curved surfaces, 140
etchings, 140
habit, 138
inclusions, 141
striations, 140
twinning, 139
Crystallography, 1–83
definition, 1
Cube, 14, 18, 21
Curved surfaces of crystals, 140
Dana's symbols, 9
Dendritic 144
Dichroism, 124
Dielectric induction, 184
Dihexagonal pyramid, 34
prism, 35, 39
Diploid, 21
Direction of rotation, 170
Ditetragonal prism, 26, 32
pyramid, 25
Dodecahedron, 14, 18, 21
Domes, macro, 50, 51, 63
brachy, 50, 51, 53, 63

ortho, 56, 57
Double refraction, strength of in uniaxial crystals, 166
Drawing crystals, 76
Drusy, 145
Dull in lustre, 154
Elastic, 146
Electrical characters of crystals, 183
Elements, 189
Etching figures, 149
Etchings of crystals, 140
Expansion of crystals, 181
measurement, 181
change of angle, 182
change of optical characters by, 182
Extinction between crossed nicols, 161
Extinction directions, 167, 173
Fibrous, 143
Feel, terms used, 152
Flame colorations, 91
structure of, 87
oxidizing, 87
reducing, 88
Flaming, 106
Fletcher lamp, 85
Flexible, 146
Fluorides, 131
Fluorine, summary of tests, 115
see also, 101, 108, 132
Fluorescence, 155
Foliated, 143
Form, ideal, 8
Form, ideal determination of, 11
Forms, definition, 8
Formula of mineral, determining, 188, 161
Fracture, description of terms, 148
Fuess goniometer, 73
Fuess microscope, 161
Fusibility, scale of, 90
how to test, 90
Fusion, manner of, 91

Gas blowpipe, 84
Geode, 145
Gliding planes, 148
Gold from iron minerals, 196
minerals of, 286
uses and extraction, 286
tests for, 99, 107, 127, 131
Gold, uses of with beads, 106
Goniometers, 72
Granular, 143
Greasy luster, 154
Gypsum plate, 167

Habit of crystals, 138
Hand-goniometers, 72
Hardness, definition and determination, 145
scale of, 145
Heat rays, transmission, 180
Heating power of flame, 88
Heavy liquids, use of, 151
Hemi prism, 63
pyramid, 55
Hemimorphic class, 42, 52
brachy dome, 53
macro dome, 53
pyramid, 43, 53
ditrigonal pyramid, 43
hexagonal pyramid, 43
trigonal pyramid, 43
Hexagonal crystals, optical characters, 165
Hexagonal prism of first order, 35, 37, 45, 46
second order, 35, 37, 39, 43, 45, 46
third order, 37, 46
pyramid of first order, 35, 38
of second order, 36, 37, 39
Hexagonal system, 33–47
axes, 33
classification, 33
definition, 33
drawing axial cross, 78
Hexagonal system, dihexagonal pyramid class
symmetry, 33
general form, 33
limit forms, 34
combination, 36
Hexagonal system, hemimorphic class
general form, 43
limit forms, 43
combination, 43
Hexagonal system, scalenohedral class
symmetry, 39
general form, 39
limit forms, 39
Domes, clino, 56, 57

Hexagonal system, scalenohedral class, combination, 40
Hexagonal system, third order pyramid class symmetry, 37
general form, 37
limit forms, 37
combinations, 38
Hexagonal system, third order rhombohedron class, 46
general form, 46
limit forms, 46
combinations, 47
Hexagonal system, trapezohedral class, 44
general forms, 44
limit forms, 44
combinations, 45
Hexagonal twins
plane a face of a rhombohedron, 68
the basal pinacoid, 68
a face of first order prism, 69
a face of second order prism, 69
Hexahedron or cube, 14, 18, 21
Hextetrahedron, 18
Hexoctahedron, 13
Hydrogen minerals, 337
Hydrous silicates, 383
Hydroxides, 189
Ideal forms, definition, 8
Impalpable, 143
Inclusion of crystals, 141
Incrustation, 145
Index of refraction, 156
of an isometric crystal, 164
uniaxial crystals, 166
biaxial crystals, 172
Indices, 10
Indices of refraction, biaxial crystals, 172
Indium, tests for, 95
Interchangeable axes, 6
Interference between crossed nicols, 161
Interference color as a test, 167, 173
colors with white light, 162
Interference phenomena
in optically uniaxial crystals, 166
with convergent light, 168
in optically biaxial crystals, 172
with convergent light, 173
Iodides, 189
Iodine, summary of tests, 115
see also, 101, 108, 131
Iridescence, definition, 155
Iridium minerals, 289
Iridium, uses and extraction, 289
Iron, minerals of, 194
uses of, 194
summary of tests, 116
see also, 99, 102, 105, 107, 109, 126, 128, 130
Isometric crystals
optical character, 164
drawing axial cross, 76
Isometric system, 12
axes of, 6, 12
definition, 12
Isometric system, diploid class, 20
general form, 21
limit forms, 21
combination, 21
Isometric system, hexoctahedral class, 12
general form, 13
limit forms, 13, 14
combinations, 16
Isometric system, hextetrahedral class, 18
general form, 18
limit forms, 18
combinations, 19
Isometric twins, 65
plane, an octahedron face, 64
a cube face, 65
a dodecahedron face, 66
Isomorphism, 187
Isotropic crystals, 164
absorption, 177
pleochroism, 177
Jolly's balance, use of, 151

Klein's solution, 151

Lamellar, 143
Lamp, the blowpipe, 84, 85
oils used in, 85
Laws of crystals, 2
of constancy of interfacial angles, 2
of symmetry, 3
of simple mathematical ratio, 8
Lead, minerals of, 241
uses and extraction, 241
summary of tests, 116
see also, 97, 98, 99, 102, 107, 109, 127, 128

Lead, uses of with beads, 106
Lithium, summary of tests, 117
see also, 95, 109, 133
Lustre, definition, 154
description of terms, 154

Macro dome, see dome
pinacoid, see pinacoid
pyramid, see pyramid
Magnesium, minerals of and their uses, 317
summary of tests, 117
see also, 99, 108, 130, 134
Magnesium ribbon, tests with, 108
Magnetic characters of crystals, 183
Malleable, 146
Mammillary, 144
Manganese, minerals of, 214
uses of, 214
summary of tests, 117
see also, 105, 107, 109, 129
Massive, 142
Mattrasses, see closed tubes
Measurement of crystal angles, 72
Mercury, minerals of, 276
uses and extraction, 276
summary of tests, 118
see also, 98, 102, 107, 128, 133
Metallic lustre, 154
Metasilicates, 357
Micaceous, 143
Mica plate, 167
wedge, 167
Microscope, polarizing, 161
Fuess, 161
Miller's symbols, 9
Minerals, distinctions of, 137
characters of, 137, *et seq.*
tables, 397
Mineralogy, definition, 137
Miscellaneous apparatus, 86
Moh's scale of hardness, 144
Molybdates, 190
Molybdenum, minerals of, 261
uses, 262
summary of tests, 118
see also, 97, 98, 99, 105, 107, 129, 133
Monoclinic crystals
optical characters, 171
distinctions, 176
drawing axial cross, 77
Monoclinic system, 55
axes of, 6, 55
definition, 55
Monoclinic system, prismatic class, 55
general form, 55
limit forms, 56, 57
combinations, 58
Monoclinic twins, 70
plane, the ortho-pinacoid, 70
basal pinacoid, 70
a dome face, 70
Negative crystals, uniaxial, 166
biaxial, 172
Nickel, minerals of, 222
uses of, 222
extraction of, 222
summary of tests, 119
see also, 99, 105, 106, 107, 109, 126, 129
Nitrates, 189
Nitric acid, summary of tests, 119
see also, 131
Nodular, 143
Non-metallic lustre, 154
Normal incidence, 157
Notation, methods of, 9

Octahedron, 15, 21
Odors in closed tubes, 101
in open tubes, 103
terms used, 153
Oils used in lamps, 85
Oölitic, 144
Opalescence, 155
Opaque, 156
Open tubes, uses of, 102
reactions in, 103
Optic axes, determination of angle, 175
Optic axis, uniaxial, 165
biaxial, 171
Optical characters, 154
determination, 168
Optical characteristics, 164, *et seq.*
Optical distinctions, 176
Optical principal sections,
uniaxial, 165
biaxial, 171
Optically isotropic crystals, 164
uniaxial crystals, 165
biaxial crystals, 171

Ortho dome, see dome
pinacoid, see pinacoid
prism, see prism
pyramid, see pyramid
Orthorhombic crystals
optical characters, 171
distinctions, 176
drawing axial cross, 77
Orthorhombic system, 48
definition, 48
axes in, 6, 48
series, 48
selection of unit plane, 48
Orthorhombic system, hemimorphic class, 52
general form, 53
limit forms, 53
combinations, 53
Orthorhombic system, pyramidal class, 49
general form, 49
limit forms, 50
combinations, 52
Orthorhombic twins, 69
plane, a prism face, 69
a dome face, 69
a pyramid face, 69
Orthosilicates, 367
Oxidation by means of blowpipe, 88
Oxides, 189
Oxidizing flame, 87, 88

Parameters, 9
Parting, 149
Pearly lustre, 154
Penfield's solution, 151
Percussion figures, 149
Phosphates, 190
Phosphorescence, 155
Phosphorus, summary of tests, 119
see also, 108, 132
Physical characters of minerals, 137
Piezoelectricity, 186
Pinacoid, basal, 26, 30, 31, 35, 37, 39 45, 46, 57, 62
brachy, 50, 51, 63
Pinacoid, clino, 56, 57
macro, 50, 63
ortho, 56, 57
Pisolitic, 144
Plane, basal, 43, 53
Plane of polarized light, 159
Planes of symmetry, 5
of vibration, 158
Plaster tablets, methods of use, 96
reactions obtained on, 97, 98
preparation, 85
Platinum minerals, 289
Platinum production, 289
Play of color, 155
Pleochroism, 177
in optically uniaxial crystals, 178
in biaxial crystals, 179
Plumose, 144
Polariscope, description and use
for parallel light, 160
for convergent light, 163
Polarized light, 159
Polysilicates, 351
Positive crystals, uniaxial, 166
biaxial, 172
Potassium, minerals of, 291
uses, 291
summary of tests, 119
see also, 95, 133, 135
Potassium chlorate, reactions with, 109
bisulphate, 108
Principal sections, optical uniaxial, 165
biaxial, 171
Principal vibration directions, 171
Prism, brachy, 50, 51
clino, 58
dihexagonal, 35, 39
ditetragonal, 26, 32
ditrigonal, 43, 45
hemi, 63
macro, 50, 51
of first order, 26–31
of second order, 26, 30, 31
of third order, 30
ortho, 58
rhombic, 53
trigonal, 39, 43
unit, 50, 51, 58
Pyramid
clino, 56
dihexagonal, 34
ditetragonal, 25
hemi, 55
of first order, 27, 30
of second order, 27, 30, 32

Pyramid, of third order, 37
ortho, 56
trigonal, 45
unit series, 56
Pyramid, hemimorphic, 53
ditrigonal, 43
hexagonal, 43
trigonal, 43
Pyritohedron, 21
Pyroelectricity, 185

Quarter undulation mica plate, 167
Quartz wedge, 167

Radiating, 145
Reducing flame, 88, 89
Reduction, 88
Reduction color tests, 106
Reflection, total, 157
Reflection goniometers, 72
Refraction, definition, 156
double, 158
index of, 156
in plane parallel plates, 157
principal indices of biaxial crystals, 172
Reniform, 143
Resinous luster, 154
Reticulated, 144
Rhombic prisms, 53
Rhombohedron of the first order, 40, 45, 46
of second order, 47
of third order, 46
Rock, definition 138
Rotation, direction of, 170
Rubidium, tests for, 95

Salt of phosphorus, action of as flux, 104
reactions with, 105
bead, how to make, 88
Scale of hardness, Moh's, 145
fusibility, *v.* Kobell's, 90
Scalenohedron, hexagonal, 39
tetragonal, 30
Schemes for blowpipe analysis, 125
for determination of minerals, 396
Sclerometer, 146
Sectile, 147
Selenides, 189
Selenium, summary of tests, 120
see also, 97, 98, 99, 102, 127
Sheaf like, 144
Silica, 342
Silicates, and their uses, 342
Silicates, 191
Silicon, summary of tests, 120
see also, 99, 130
Silky lustre, 154
Silver, minerals of, 278
uses and extraction, 278
summary of tests, 120
see also, 99, 107, 127, 131
Simple mathematical ratio, law of, 8
Soda, action of as flux, 98
reactions with, 99
Sodium, minerals of, 293
reactions with, 100
uses, 293
summary of tests, 121
see also, 95, 133
Sodium thiosulphate, method of using, 107
reactions with, 107
Specific gravity determination, 150
Spectroscope, use of, 92
description, 93
chart, 94
Sphenoid, tetragonal, 32
Stalactitic, 144
Streak, definition and determination, 155
Striations of crystals, 140
Strontium, minerals of and their uses, 300
summary of tests, 121
see also, 99, 130, 133, 135
Sublimates in closed tubes, 101
in open tubes, 103
on charcoal, 97
on plaster, 97
Submetallic, etc., see metallic, etc.
Subsilicates, 381
Sulphates, 190
Sulphides, 189
Sulphur minerals, 335
Sulphur extraction, 335
summary of tests, 121
see also, 102, 127
Summary of blowpipe tests, 110
Surface conductivity, 180
Symbols of Weiss, Dana, and Miller, 9
Symmetry, definition of, 3
planes of, 5
law of, 3

Symmetry, true structural, 5
Systems, the six crystal, 6
axes of, 9
classes of, 5
determinations of, 7
Tables for mineral determination, 320
Tarnish, definition, 155
Taste, terms used, 153
Tellurides, 189
Tellurium minerals, 335
summary of tests, 121
see also, 98, 99, 102, 127
Tenacity, description of term, 146
Tetragonal crystals
optical characters, 165
drawing axial cross, 77
Tetragonal prisms of 1st order, 26
prisms of 2d order, 26
pyramid of 2d order, 27
sphenoid, 32
trisoctahedron, 15, 21
tristetrahedron, 19
Tetragonal system, definition, 23
axes, 6, 23
classification, 23
Tetragonal system, ditetragonal pyramid class, 24
symmetry of, 24
general form, 25
limit forms, 25
series and combinations, 27
Tetragonal system, scalenohedral class, 31
general form, 31
limit forms, 31
series and combinations, 32
Tetragonal system, third order pyramid class, 29
general form, 30
limit forms, 30
series and combinations, 30
Tetragonal twins, 67
Tetrahedron, 18
Tetrahexahedron, 14, 18
Tetrapyramid, 62
Thallium, tests for, 95
Thermal characters, 180
Thermo-electricity, 184
Thorium, minerals of, 239
uses of, 239
Thoulet solution, 151
Tin, minerals of, 234
uses and extraction, 234
summary of tests, 122
see also, 97, 98, 99, 102, 107, 108, 126, 127, 130
uses with fluxes, 106
uses in color tests, 106
Titanium, minerals of, 236
uses, 236
summary of tests, 122
see also, 105, 107, 108, 128, 130, 134
Titano-silicates, 395
Total reflection, 157
Translucency, definition and forms, 156
Transparent, 156
Trapezohedron, trigonal, 44
Triclinic crystals
optical character, 171
distinction, 176
drawing axial cross, 77
Triclinic system, definition, 6, 61
axes, 61
series, 61
Triclinic system, pinacoidal class, 61
general form, 62
limit forms, 62
combinations, 63
Triclinic twins, 70
Trigonal prism, see prism
pyramid, see pyramid
trapezohedron, 44
trisoctahedron, 15, 21
tristetrahedron, 19
Tube tests, 101, 102
Tungstates, 190
Tungsten, summary of tests, 122
see also, 99, 105, 107, 128
from wolframite, 196
Twin crystals drawing of, 81
Twinning crystals, 65–71, 139
definition, 65
plane, 65
axis, 65
Twins, 65
hexagonal, 68
isometric, 65
monoclinic, 70
orthorhombic, 69
tetragonal, 67
triclinic, 70

Types, 189

Uniaxial crystals,
optical characters, 165
absorption, 178
pleochroism, 178
Unit prism, 50, 51, 58
pyramid, 56
Uranium, minerals of, 260
uses, 260
summary of tests, 123
see also, 105, 107, 129

Vanadinates, 191
Vanadium, summary of tests, 123
see also, 99, 105, 107, 129
Vibration, directions, 171
Vibrations, planes of, 158
Vitreous lustre, 154
Volatilization, elements affected, 95

Water, tests for, 101, 133
Weiss's symbols, 9
Westphal's balance, use of, 152

Zeolites, 384
Zinc, minerals of, 228
use of, 228
extraction of, 228
summary of tests, 123
see also, 97, 99, 102, 107, 108, 126

INDEX TO MINERALS

Acmite, 360
Aegirite, 360
Actinolite, 364
Adamantine spar, 324
Adularia, 354
Agate, 346, 348
Agolite, 392
Aikinite, 253
Alabandite, 214
Alabaster, 306, 307
Albite, 354
Alexandrite, 330
Allanite, 380
Almandite, 370
Aluminite, 327
Alum stone, 328
Alunite, 327
Alunogen, 328
Amalgam, 280
Amazonstone, 354
Amber, 339
Amber mica, 389
Amethyst, 348
Amphibole, 363
Analcite, 385
Anatase, 238
Andalusite, 377
Andradite, 370
Anglesite, 245
Anhydrite, 305
Ankerite, 316
Annabergite, 225
Anorthite, 356
Anorthoclase, 354
Antimony, 258
Apatite, 308
Aphthitalite, 291
Apophyllite, 384
Aquamarine, 365
Aragonite, 310
Argentine, 313
Argentite, 280
Aragonite, 310
Arsenic, 255
Arsenolite, 257
Arsenopyrite, 200
Asbestus, 345, 364
Asparagus stone, 308
Asphaltum, 339
Atacamite, 272
Augite, 358, 360
Autunite, 261
Aventurine, 348
Axinite, 380
Azurite, 274

Balas ruby, 319, 320
Barite, 298
Barytocalcite, 300
Bastite, 358
Bauxite, 326
Beryl, 365
Biotite, 389
Bismite, 254
Bismuth, 252
Bismuth ochre, 254
Bismuthinite, 253
Bismutite, 254
Black hematite, 217
  jack, 228
  lead, 341
  mica, 389
  oxide of copper, 271
  oxide of manganese, 216
Blende, 228
Bloodstone, 349
Blue carbonate of copper, 274
  iron earth, 209
  stone, 344
  vitrol, 272
Bog iron ore, 207
  manganese, 217
Boracite, 334
Borax, 332
Bornite, 267
Boronatrocalcite, 332
Bort, 341
Bournonite, 243
Braunite, 215
Brimstone, 335
Brittle silver ore, 283
Brochantite, 272
Bromargyrite, 285
Bromyrite, 285
Bronzite, 358
Brookite, 238
Brown clay ironstone, 208
  hematite, 207
Brucite, 318

Calamine, 231
Calaverite, 289
Calc spar, 311
Calcite, 311
Calomel, 277
Cancrinite, 368
Capillary pyrites, 223
Carbonado, 341
Carnelian, 349
Cassiterite, 235
Cat's-eye, 330, 348
Celestite, 300
Cerargyrite, 284
Cerussite, 247
Ceylonite, 320
Chabazite, 385
Chalcanthite, 272
Chalcedony, 346, 348
Chalcocite, 266
Chalcopyrite, 267
Chalk, 313
Chesterlite, 354
Chiastolite, 377, 391
Chili saltpetre, 296
China clay, 394
Chloanthite, 225
Chondrodite, 381
Chromic iron, 211
Chromite, 211
Chrysoberyl, 330
Chrysocolla, 274
Chrysolite, 371
Chrysoprase, 349
Chrysotile, 345
Cinnabar, 277
Clausthalite, 244
Clay ironstone, 205
Clinochlore, 390
Coal, mineral, 338
Cobalt glance, 220
  pyrites, 219
Cobaltite, 220
Colemanite, 333
Columbite, 212
Copiapite, 208
Copper, 265
Copper glance, 266
Copper nickel, 224
  pyrites, 267
  uranite, 261
  vitriol, 272
Copperas, 209
Cordierite, 367

Corundum, 324
Crocidolite, 365
Crocoite, 249
Cryolite, 323
Cube ore, 210
Cuprite, 270
Cyanite, 366
Cymophane, 330

Dark ruby silver, 282
Datolite, 378
Descloizite, 250
Desmine, 385
Diallage, 360
Diamond, 338, 340
Diaspore, 326
Dichroite, 367
Diopside, 360
Dioptase, 275
Dog-tooth spar, 313
Dolomite, 314
Dry-bone, 230

Edenite, 364
Eisstein, 323
Elæolite, 367
Electric calamine, 231
Embolite, 285
Emerald, 365, 366
Emerald nickel, 225
Emery, 324
Enargite, 268
Enstatite, 358
Epidote, 379
Epsomite, 318
Epsom salt, 318
Erythrite, 221

False topaz, 348
Fayalite, 372
Feather ore, 244
Feldspar, 352
Felsite, 354
Fibrolite, 377
Fiorite, 351
Ferruginous quartz, 348
Fire opal, 351
Flint, 349
Flos ferri, 310
Fluorite, 304
Fluor spar, 304
Fontainbleau sandstone, 313
Fool's gold, 197
Franklinite, 203
French chalk, 392
Fullers earth, 346

Galena, 242
Galenite, 242
Garnet, 369
Garnierite, 226
Gay-Lussite, 297
Geyserite, 351

Gibbsite, 326
Glauber salt, 296
Glauberite, 295
Glaucophane, 365
Goethite, 207
Gold, 287
Goshenite, 366
Goslarite, 229
Graphic tellurium, 288
Graphite, 338, 341
Gray antimony, 258
copper ore, 269
Greasy quartz, 348
Greenockite, 233
Green carbonate of copper, 273
Grossularite, 370
Guano, 309
Gypsum, 306

Halite, 294
Hausmannite, 215
Hauynite, 368
Heavy spar, 298
Hedenbergite, 360
Heliotrope, 349
Hematite, 204
Hessite, 281
Heulandite, 385
Hiddenite, 361
Hornblende, 363, 364
Horn silver, 284
mercury, 277
Horse flesh ore, 267
Hyacinth, 374
Hyalite, 351
Hyalosiderite, 372
Hydraulic limestone, 313
Hydrozincite, 230
Hydrohematite, 207
Hypersthene, 358

Ice, 337
Iceland spar, 311, 313
Idocrase, 373
Ilmenite, 206
Indianite, 356
Infusorial earth, 344, 351
Iodargyrite, 285
Iodyrite, 285
Iolite, 367
Iridosmine, 290
Iron, 196
Iron pyrites, 197
Isinglass, 388

Jade, 364
Jadeite, 361
Jamesonite, 244
Jasper, 346

Kainite, 292
Kalinite, 292
Kaolin, 394
Kaolinite, 394
Kermesite, 259
Krennerite, 289
Kyanite, 366

Labradorite, 356
Lapis Lazuli, 369
Lazulite, 329
Lazurite, 369
Lead, 242
Lepidolite, 390
Leucite, 357
Leucopyrite, 202
Libethenite, 272
Light ruby silver, 281
Lime feldspar, 356
soda feldspar, 356
uranate, 261
Limestone, 311, 313
Limonite, 207
Linarite, 246
Linnæite, 219
Lithia mica, 390
Lithographic limestone, 313
Lodestone, 202
Löllingite, 202
Loxoclase, 354

Magnesian limestone, 314
mica, 389
Magnesite, 319
Magnetic iron ore, 202
Magnetic pyrites, 197
Magnetite, 202
Malachite, 273
Malacolite, 360
Manganblende, 214
Manganite, 216
Marble, 311, 313
Marl, 313
Marcasite, 199
Martite, 205
Mascagnite, 297
Meerschaum, 393
Melaconite, 271
Melanterite, 209
Melilite, 374
Menaccanite, 206
Mercury, 276
Mica, 345
Microcline, 354
Milky quartz, 348
Millerite, 223
Mimetite, 247
Mineral coal, 338
Minium, 244
Mirabilite, 296
Mispickel, 200
Misy, 208
Molybdenite, 262
Molybdite, 262
Monazite, 240
Mundic, 197

Muscovite, 388

Native antimony, 258
arsenic, 255
boracic acid, 331
bismuth, 252
copper, 265
gold, 287
iron, 196
lead, 242
mercury, 276
platinum, 290
silver, 279
sulphur, 335
tellurium, 337
ultramarine, 369
vermilion, 277

Natrolite, 387
Needle ore, 253
Nephelite, 367
Nephrite, 364
Niccolite, 224
Nickel bloom, 225
Nigrine, 237
Nitre, 292
Noselite, 368
Noumeite, 226

Ochre, red, 205
yellow, 208
Octahedrite, 238
Oligoclase, 355
Olivenite, 273
Olivine, 371
Onyx, 313, 349
Opal, 350
jasper, 351
Orangite, 240
Orpiment, 256
Orthoclase, 352
Osteolite, 309
Ozocerite, 339

Pandermite, 333
Pearl sinter, 351
Pearl spar, 314
Pectolite, 362
Pencil-stone, 395
Pentlandite, 224
Peridot, 371
Pericline, 354
Perovskite, 317
Perthite, 354
Petalite, 352
Petroleum, 339
Pharmacolite, 310
Pharmacosiderite, 210
Phenacite, 372
Phlogopite, 390
Phosgenite, 248
Phosphate rock, 308
Phosphorite, 309
Picotite, 320
Pitchblende, 260
Plasma, 349
Platinum, 290
Plumbago, 341
Plumbocalcite, 314
Polybasite, 284
Potash alum, 292
feldspar, 352
mica, 388
Prase, 349
Precious opal, 351
garnet, 370
Prehnite, 380
Priceite, 333
Prochlorite, 391
Proustite, 281
Psilomelane, 217
Purple copper ore, 267
Pyrargyrite, 282
Pyrite, 197
Pyrolusite, 216
Pyromorphite, 246
Pyrope, 370
Pyrophyllite, 395
Pyroxene, 358
Pyrrhotite, 197

Quartz, 346

Realgar, 256
Red antimony, 259
hematite, 205
iron ore 204
ochre, 205
oxide of copper, 270
silver ore, 281
zinc ore, 229
Rensselaerite, 392
Rhodochrosite, 218
Rhodonite, 362
Rhyacolite, 354
Ripidolite, 391
Rock crystal, 348
gypsum, 307
meal, 314
salt, 294
Rose quartz, 348
Ruby, 324
copper, 270
spinel, 319
silver, 281, 282
Rutile, 237

Sal ammoniac, 297
Salt, 294
Saltpetre, 292
Sandstone, 344, 349
Sanidin, 354
Sapphire, 324
Sard, 349
Sardonyx, 349
Sassolite, 331
Satin-spar, 307, 313
Scapolite, 372
Scheelite, 316
Schorl, 381
Scorodite, 210
Selenite, 306, 307
Semi opal, 351
Sanarmontite, 260
Sepiolite, 393
Serpentine, 392
Siderite, 210
Siliceous sinter, 351
Sillimanite, 377
Silver, 279
Silver glance, 280
Slate, 344
Smaltite, 221
Smithsonite, 230
Smoky quartz, 348
Snow, 337
Soapstone, 391
Soda feldspar, 354
lime feldspar, 355
Soda nitre, 296
Sodalite, 368
Spartaite, 314
Spathic iron, 210
Specular iron, 204
Spessartite, 370
Spha'erite, 228
Sphene, 394
Spinel, 319
Spodumene, 360
Stalactite, 313
Stalagmite, 313
Stannite, 235
Stassfurtite, 334
Staurolite, 382
Steatite, 392
Stephanite, 283
Stibnite, 258
Stilbite, 385
Stolzite, 251
Stream tin, 235
Stromeyerite, 281
Strontianite, 302
Succinite, 339
Sulphur, 335
Sylvanite, 288
Sylvite, 291

Talc, 344, 392
Tantalite, 212
Tellurium, 337
Tennantite, 268
Tenorite, 271
Tetradymite, 254
Tetrahedrite, 269
Thenardite, 295
Thomsonite, 387
Thorite, 240
Thulite, 379
Tin stone, 235

Tin pyrites, 235
Tinkal, 332
Titanic iron ore, 206
Titanite, 395
Topaz, 375
Torbernite, 261
Touchstone, 349
Tourmaline, 381
Travertine, 313
Tremolite, 364
Tridymite, 350
Triphylite, 209
Triplite, 218
Tripolite, 351
Trona, 296
Troostite, 231
Turgite, 207
Turquois, 328

Ulexite, 333
Umber, 208
Uralite, 365
Uraninite, 260
Uvarovite, 370
Urao, 296

Valentinite, 260
Vanadinite, 249
Verd-antique, 391
Vesuvianite, 373
Vivianite, 209

Wad, 217
Water, 337
Wavellite, 329
Wernerite, 372
White iron pyrites, 199
lead ore, 247
mica, 388
Willemite, 231
Witherite, 299
Wolframite, 212
Wollastonite, 361
Wood-opal, 351
Wood tin, 235
Wulfenite, 250

Yellow copper ore, 267
Yellow ochre, 208
Yellow quartz, 348

Zaratite, 225
Zinc blende, 228
vitriol, 229
bloom, 230
Zincite, 229
Zircon, 374
Zoisite, 379